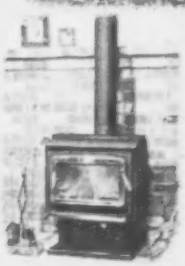

2002 ANNUAL AIR QUALITY REPORT FOR PRINCE GEORGE

Environmental Protection Division
Ministry of Water, Land and Air Protection
Omineca and Peace Regions

Prince George, British Columbia

April 2004

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TABLE OF CONTENTS

Page

PREFACE ix

OBJECTIVES 1

EXECUTIVE SUMMARY 2

1. PRINCE GEORGE MONITORING NETWORK 4

2. INDUSTRIAL EMISSION SOURCE STATUS 6
   - 2.1 Total Reduced Sulphur Source Emission Changes 7
   - 2.2 Sulphur Dioxide Source Emission Changes 9
   - 2.3 Total Particulate Source Emission Changes 11

3. METEOROLOGICAL INFORMATION FOR 2002 15
   - 3.1 Analysis of Winds 16
     - 3.1.1 Wind Trends 24
   - 3.2 Analysis of Precipitation 25
   - 3.3 Analysis of Solar Radiation 26
   - 3.4 Analysis of Temperature 29
   - 3.5 Analysis of Relative Humidity 31

4. AMBIENT AIR QUALITY RESULTS AND TRENDS
   - 4.1 Total Reduced Sulphur (TRS) Results 32
     - 4.1.1 TRS Annual Trends 39
     - 4.1.2 Comparison of TRS Levels with Other B.C. Locations 44
   - 4.2 Sulphur Dioxide (SO_2) Results 46
     - 4.2.1 SO_2 Annual Trends 52
     - 4.2.2 Comparison of SO_2 Levels with Other B.C. Locations 56
   - 4.3 Nitrogen Dioxide (NO_2) Results 58
     - 4.3.1 NO_2 Annual Trend 63
     - 4.3.2 Comparison of NO_2 Levels with Other B.C. Locations 65
   - 4.4 Ozone (O_3) Results 67
     - 4.4.1 O_3 Annual Trend 72
     - 4.4.2 Comparison of O_3 Levels with Other B.C. Locations 75
   - 4.5 Particulate Matter (PM_{10}) Results 76
     - 4.5.1 PM_{10} Continuous Monitoring Results 79
     - 4.5.2 PM_{10} Annual Trends 85
     - 4.5.3 Comparison of PM_{10} Levels with Other B.C. Locations 92
     - 4.5.4 Particulate Matter ($PM_{2.5}$) Results 96
     - 4.5.5 $PM_{2.5}$ Continuous Monitoring Results 96
     - 4.5.6 $PM_{2.5}$ Annual Trend 99

105-03528/

4.5.7 Comparison of $PM_{2.5}$ Levels with Other B.C. Locations 102

5. **AIR QUALITY ADVISORIES** 104

6. **CONCLUSIONS**
6.1 Emission Source Changes 105
6.2 Air Quality Acceptability and Trends 106
6.3 Recommendations 107

7. **REFERENCES** 108

APPENDICES

A B.C. Ambient Air Quality Objectives 111

B Industry Shutdowns 112

C Industrial Operating Rates 114

D Monitoring Program Notes
D-I Continuous Monitor Audit Results 115
D-II Instrument Operating Hours 116
D-III Instrument Malfunctions 116

E Archived Data 117
E-1 Additional TRS Results 117
E-2 Additional SO_2 Results 118
E-3 Additional PM_{10} Results 119
E-4 Total Suspended Particulate (TSP) Results 121
E-4.1 Sulphates, Nitrates and Lead in Total Suspended Particulate Results 125
E-4.2 Silicates in PM_{10} Results 127
E-5 Carbon Monoxide (CO) Results 127
E-6.1 Formaldehyde (HCHO) Results 128
E-6.2 Volatile Organic Compounds (VOC) Results 129
E-6.3 Polycyclic Aromatic Hydrocarbons (PAH) Results 130
E-7 Dustfall Results 131

F Photographs of Monitoring Sites in Prince George 134

G Glossary 136

TABLES

1.1	Prince George Air Quality Monitoring Program for 2002	4
2.1	Trend in Total Pulp Produced in Pulp Mills Since 1990 (Tonnes/day)	6
2.2.1	Husky Refinery Annual Average Stream Day Crude Under Normal Operating Conditions	6
2.3	Summary of Annual TRS Emissions (as H_2S) from the Three Pulp Mills and Husky Oil Refinery Under Normal Operating Conditions (Tonnes per Year)	8
2.4	Summary of Annual SO_2 Emissions from the Three Pulp Mills and Husky Oil Refinery Under Normal Operating Conditions (Tonnes per Year)	10
2.5	2002 Particulate Emission Rates from the Pulp Mills (kg/min)	12
2.6	Summary of Annual Total Particulate Emissions from the Three Pulp Mills Under Normal Operating Conditions (Tonnes per Year)	12
3.1	2002 Meteorological Stations with Percent Valid Data	15
3.2	Monthly Distribution of Hours of Bright Sunlight	28
3.3	Monthly Average Temperatures Recorded at Sites in Prince George in 2002	30
4.1.1	2002 Monthly Summary of TRS Data at Plaza	35
4.1.2	2002 Monthly Summary of TRS Data at Jail	35
4.1.3	2002 Monthly Summary of TRS Data at Lakewood	36
4.1.4	Annual Trend Summary of TRS Data at Plaza	39
4.1.5	Annual Trend Summary of TRS Data at Jail	40
4.1.6	Annual Trend Summary of TRS Data at Lakewood	40
4.1.7	Percentiles of 1-hour TRS Levels Recorded at the Three TRS monitoring Sites	42
4.1.8	Comparison of 2002 with Previous Rates of Seasonal Exceedances of the TRS One-Hour Level A and B Objectives	43
4.2.1	2002 Monthly Summary of SO_2 Data at Jail	47
4.2.2	2002 Monthly Summary of SO_2 Data at Plaza	47
4.2.3	2002 Monthly Summary of SO_2 Data at CBC Transmitter	48
4.2.4	Annual Trend Summary of SO_2 Data at Jail	53
4.2.5	Annual Trend Summary of SO_2 Data at Plaza	53
4.2.6	Annual Trend Summary of SO_2 Data at CBC	54
4.2.7	Percentiles of 1-hour SO_2 Levels Recorded at the Three SO_2 Monitoring Sites	55
4.3.1	2002 Monthly Summary of NO_2 Data at Plaza	59
4.3.2	Annual Trend Summary of NO_2 Data at Plaza	64
4.3.3	Percentiles of 1-hour NO_2 and NO Levels Recorded at Plaza	65
4.4.1	2002 Monthly Summary of O_3 Data at Plaza	68
4.4.2	Annual Trend Summary of O_3 Data at Plaza	73
4.4.3	Percentiles of 1-hour and 8-hour O_3 Levels Recorded at Plaza	74
4.5.1	2002 Airshed PM_{10} Summary	77

4.5.2 Comparison of the Six-day (NAPS) with the Full Year Data 78
4.5.3 2002 Monthly Summary of Continuous PM_{10} Data at Plaza 80
4.5.4 2002 Monthly Summary of Continuous PM_{10} Data at Gladstone 80
4.5.5 2002 Monthly Summary of Continuous PM_{10} Data at BCR 81
4.5.6 Annual Trend Summary of Non-Continuous PM_{10} Data at Van Bien.... 86
4.5.7 Annual Trend Summary of Non-Continuous PM_{10} Data at Lakewood.. 86
4.5.8 Annual Trend Summary of Non-Continuous PM_{10} Data at the CNR Site 87
4.5.9 Annual Trend Summary of Non-Continuous PM_{10} Data at Plaza 87
4.5.10 Annual Trend Summary of Continuous PM_{10} Data at Plaza 88
4.5.11 Annual Trend Summary of Continuous PM_{10} Data at the BCR-Warehouse. 88
4.5.12 Annual Trend Summary of Continuous PM_{10} Data at Gladstone..... 88
4.5.13 Percentiles of 1-hour PM_{10} Levels Recorded at the Continuous PM_{10} monitoring Sites 90
4.5.14 Percentiles of 24-hour PM_{10} Levels Recorded at the Continuous PM_{10} monitoring Sites 91
4.5.15 2002 Monthly Summary of Continuous $PM_{2.5}$ Data at Plaza 97
4.5.16 Annual Trend Summary of Non-Continuous $PM_{2.5}$ Data at Plaza 99
4.5.17 Annual Trend Summary of Continuous $PM_{2.5}$ Data at Plaza..... 99
4.1.18 Percentiles of 1-hour and 24-hour $PM_{2.5}$ Levels Recorded at the Plaza Site..... 101

5.1 Advisories Issued for Prince George in 2002 104

A - 1 Provincial Air Quality Objectives ($\mu g/m^3$) 111

B - 1 Pulp Mill Shutdown Periods 112
B - 2 Husky Refinery Shutdown Periods..... 113

C - 1 Typical Operating Rate of Pulp Mills in 2001 (Tonnes/day) 114
C - 2 2002 Husky Refinery Typical Operating Rate 114

D - 1 2002 Continuous Monitor Audit Results..... 115
D - 2 Instrument Percent Valid Data for 2002 116

E.1.1 Annual Trend Summary of TRS Data at Foreman Flats 117
E.1.2 Annual Trend Summary of TRS Data at Van Bien 118
E.1.3 Annual Trend Summary of TRS Data at Glenview 118
E.2.1 Annual Trend Summary of SO_2 Data at College Heights..... 119
E.3.1 Annual Trend Summary of Non-Continuous PM_{10} Data at Gladstone 119
E.3.2 Annual Trend Summary of Non-Continuous PM_{10} Data at the BCR-Engineering Bldg. 120
E.3.3 Annual Trend Summary of Non-Continuous PM_{10} Data at the BCR-Warehouse. 120
E.3.4 Annual Trend Summary of Continuous PM_{10} Data at the Hart Highlands. 120

E.3.5 Annual Trend Summary of Continuous PM_{10} Data at the Glenview School - Hart. 120
E.3.6 Annual Summary of Non-Continuous PM_{10} Data at Sintich Trailer Park 121
E.4.1 Annual Trend Summary of Non-Continuous TSP Data at Plaza Using the Federal Monitor 122
E.4.2 Annual Trend Summary of Non-Continuous TSP Data at Plaza 123
E.4.3 Annual Trend Summary of Non-Continuous TSP Data at Van Bien 123
E.4.4 Annual Trend Summary of Non-Continuous TSP Data at Jail 123
E.4.5 Annual Trend Summary of Non-Continuous TSP Data at Lakewood 124
E.4.6 Annual Trend Summary of Non-Continuous TSP Data at Foreman Flats 124
E.4.7 Annual Trend Summary of Non-Continuous TSP Data at Gladstone 124
E.4.8 Annual Trend Summary of Non-Continuous TSP Data at 5th Avenue Firehall 125
E.4.9 Annual Trend Summary of Non-Continuous TSP Data at Community Service Centre 125
E.4.10 Annual Trend Summary of Non-Continuous TSP Data at Seymour 125
E.4.11 Annual Trend Summary of (Non-Continuous) Sulphates, Nitrates and Lead in TSP at Plaza 126
E.4.12 Silicon Levels Recorded at Sites in Prince George 127
E.5.1 1997-98 Monthly Summary of Carbon Monoxide (CO) at Sites in Prince George 127
E.6.1 1995-97 Monthly Summary of Formaldehyde ($\mu g/m^3$) Data at Sites in Prince George 128
E.6.2 Concentrations of Various VOC ($\mu g/m^3$) Recorded from December 1994 to June 1995 130
E.6.3 Concentrations of Various PAHs ($\times 10^{-3}$ $\mu g/m^3$) Recorded from December 1994 to June 1995 131
E.7.1 Summary of Dustfall Data at Plaza ($mg/dm^2.d$) 132
E.7.2 Summary of Dustfall Data at Foreman Flats ($mg/dm^2.d$) 132
E.7.3 Summary of Dustfall Data at Van Bien ($mg/dm^2.d$) 133
E.7.4 Summary of Dustfall Data at Lakewood ($mg/dm^2.d$) 133

FIGURES

1.1 Prince George Monitoring Sites 5

2.1 Industrial TRS Emission Trends 9
2.2 Industrial SO_2 Emission Trends 11
2.3 Pulp Mill Total Particulate Emission Trends 13

3.1 Anemometers Used in Prince George Monitoring Program 15
3.2 Wind Rose for Northwood Meteorological Station for 2002 17
3.3 Wind Rose for P.G. Pulp Meteorological Station for 2002 17
3.4 Wind Rose for Plaza Meteorological Station for 2002 18
3.5 Wind Rose for Hart Meteorological Station for 2002 18
3.6 Wind Rose for the Airport Meteorological Station for 2002 19
3.7 Wind Rose for the UNBC Meteorological Station for 2002 19
3.8 Map of Prince George showing the Six Wind Roses for 2002 21
3.9 Percent Frequency of Vector Winds (Per Quadrant <1.0 m/s) 22
3.10 Percent Frequency of Vector Winds (Per Quadrant >1.0 m/s and <2.0 m/s) 22
3.11 Average Monthly Wind Speed (2002 and 10 Year Mean) - Prince George Airport 23
3.12 Average Monthly Wind Speed 2002 - MIS stations 24
3.13 Annual Mean Wind Speed Trend 25
3.14 Comparison of Total Monthly Precipitation at the Airport Between 2002 and the 10-Year Average 25
3.15 Total Annual Precipitation Recorded at the Prince George Airport 26
3.16 Number of Hours of Bright Sunlight Recorded in Prince George in 2002 Compared to the 30 Year Normal 27
3.17 Maximum Daily Solar Radiation Levels Received at UNBC in 2002 28
3.18 Maximum Daily Solar Radiation Levels Received at Plaza in 2002 29
3.19 2002 Maximum and Minimum Temperatures in Prince George Compared to the 1985-2001 Values 29
3.20 Monthly Pattern in Relative Humidity in Prince George in 2002 31

4.1.1 TRS Monitor Located at Plaza 32
4.1.2 TRS Pollution Rose Recorded at Plaza for 2002 33
4.1.3 2002 Monthly Average TRS Levels vs. Frequency of Selected Wind Speed and Direction 34
4.1.4 Monthly Trend in TRS Levels Recorded at Plaza Since 1995 36
4.1.5 Monthly Trend in TRS Levels Recorded at Lakewood Since 1995 37
4.1.6 Monthly Trend in TRS Levels Recorded at Jail Since 1995 38
4.1.7 Daily Trend in TRS Levels in Prince George in 2002 38
4.1.8 Annual Average Ambient TRS Levels 41
4.1.9 Rolling Annual Average Ambient TRS Levels Recorded at Sites

	in Prince George	41
4.1.10	Comparison of 2002 Annual Average TRS Levels with Other B.C. Locations	45
4.2.1	TECO SO_2 Monitor	47
4.2.2	Monthly Trend in SO_2 Levels Recorded at Plaza Since 1995	48
4.2.3	Monthly Trend in SO_2 Levels Recorded at Jail Since 1995	49
4.2.4	Monthly Trend in SO_2 Levels Recorded at CBC Since 1995	49
4.2.5	SO_2 Pollution Rose Recorded at Plaza for 2002	50
4.2.6	Annual Daily Pattern in SO_2 Levels in Prince George for 2002	51
4.2.7	Rolling Annual Average SO_2 Trend at Sites in Prince George	54
4.2.8	Comparison of 2002 Annual Average SO_2 Levels with Other B.C. Locations	57
4.3.1	Chemiluminescence NO_x Monitor	58
4.3.2	Monthly Trend in NO_2 Levels Recorded at Plaza Since 1995	60
4.3.3	NO_2 Pollution Rose Recorded at Plaza for 2002	61
4.3.4	NO Pollution Rose Recorded at Plaza for 2002	61
4.3.5	Daily Average NO_2 Pattern in Prince George in 2002	62
4.3.6	Daily Average NO Pattern in Prince George in 2002	62
4.3.7	Rolling Annual and Monthly NO_2 Trends in Prince George	63
4.3.8	Comparison of 2002 Annual Average NO_2 Levels with Other B.C Locations	66
4.3.9	Comparison of 2002 Annual Average NO Levels with Other B.C. Locations	66
4.4.1	API Ozone Monitor	67
4.4.2	Comparison of 2002 Monthly Average Ozone Levels at Plaza with Percent of Calm Winds and Total Hours of Bright Sunlight	69
4.4.3	Monthly Trend in Ozone Levels Recorded at Plaza Since 1995	70
4.4.4	O_3 Pollution Rose Recorded at Plaza for 2002	71
4.4.5	Typical Diurnal Ozone Pattern Throughout 2002	72
4.4.6	Rolling Average Annual and Monthly Ozone Trends at Prince George	73
4.4.7	Comparison of 2002 Maximum Hourly and Annual Average Ozone Levels with Other B.C. Locations	75
4.5.1	PM_{10} Non-continuous Monitor	77
4.5.2	PM_{10} TEOM Monitor	77
4.5.3	Comparison of 2002 Monthly Average PM_{10} Levels at Plaza with Winds Frequency (< 1m/s) and Precipitation Days	81
4.5.4	Monthly Trend in PM_{10} Levels Recorded at Plaza Since 1995	82
4.5.5	Monthly Trend in PM_{10} Levels Recorded at Gladstone Since 1996	83
4.5.6	Monthly Trend in PM_{10} Levels Recorded at BCR Since 1996	84
4.5.7	PM_{10} Pollution Rose Recorded at Plaza for 2002	84
4.5.8	Rolling Average Annual Mean PM_{10} Levels at Non-continuous Sites in Prince George	89

4.5.9 Annual PM_{10} Concentration Compared to the Risk Factor 92
4.5.10 Comparison of 2002 Annual Average PM_{10} Levels with Other B.C. Locations (Continuous Monitors) 94
4.5.11 Comparison of 2002 Annual Average PM_{10} Levels with Other B.C. Locations (Non-continuous Monitors) 95
4.5.12 $PM_{2.5}$ Partisol 96
4.5.13 Monthly Trend in $PM_{2.5}$ Levels Recorded at Plaza Since 1997 97
4.5.14 $PM_{2.5}$ Pollution Rose Recorded at Plaza for 2002 98
4.5.15 Rolling Annual Average Particulate Levels Recorded at Plaza 100
4.5.16 Annual $PM_{2.5}$ Concentration Compared to the Risk Factor 102
4.5.17 Comparison of 2002 Annual Average $PM_{2.5}$ Levels with Other B.C. Locations 103

Photographs of the Monitoring Sites in Prince George 134

PREFACE

This report presents a summary and assessment of the 2002 air pollutant emission sources, the ambient air quality, and the meteorological information in the Prince George airshed. This report is prepared for the use of the Prince George Air Quality Implementation Committee, and for the joint government/industry monitoring group, the Prince George Air Quality Monitoring Working Group.

The Prince George Air Quality Implementation Committee comprises representatives from:

BC WATER LAND AND AIR PROTECTION - OMINECA-PEACE REGION

REGIONAL DISTRICT - FRASER-FORT GEORGE

CITY OF PRINCE GEORGE

MINISTRY OF TRANSPORTATION

NORTHERN HEALTH AUTHORITY

UNIVERSITY OF NORTHERN B.C.

PRINCE GEORGE CHAMBER OF COMMERCE

PRINCE GEORGE AND DISTRICT MEDICAL SOCIETY

CANFOR

BCR

CN RAIL

HUSKY

CENTRAL INTERIOR WOOR PROCESSORS' ASSOCIATION

CARRIER LUMBER

All operational and maintenance costs are funded by the Prince George Air Quality Monitoring Working Group.

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The Ministry provides an air quality index that is updated twice daily during the work week, and which is accessible to the public via a telephone answering machine (565-6457). Air quality

index values for selected pollutants are also provided to the local newspaper, radio and T.V. station on a daily basis, as well as to the Weather Network, and is available on the internet at http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.summary. The Ministry also installed a 24-hour complaint line (565-4487) in June 1996 where the public can record reports of poor air quality in their area (with the option of remaining anonymous).

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OBJECTIVES

The purpose of the airshed monitoring program is to conduct an ambient air quality and meteorological monitoring program in Prince George, which is used to establish the relationship between air quality, source emissions and meteorological conditions, and to determine the acceptability of air quality based on B.C.'s air quality objectives.

This program is also being used to determine trends in air polluion and to assess the effectiveness of pollution reduction.

This report summarizes the data collected in 2002, describes the pulp mills' and Husky's major emission source status, ambient air quality and meteorological data, and includes a trend analysis of air quality. The appendices contain updated information on the pulp mills' and refinery's emission sources, audit results and operating hours of monitoring equipment at the air quality stations, periods of shutdown at the pulp mills and Husky, ambient air quality objectives, archived air quality data that is not included in the main body of the report, photographs of monitoring sites and a glossary of terms.

EXECUTIVE SUMMARY

This report summarises the data collected in the Prince George airshed for 2002 and describes the major emission source status, air quality, and meteorological data.

In 2002, eight air quality monitoring stations were in operation to measure six criteria pollutants. The parameters measured were PM_{10} (Particulate Matter less than 10 microns (μm) in size), $PM_{2.5}$ (Particulate Matter less than 2.5 microns in size), NO_x (Nitrogen Oxides), O_3 (Ozone), TRS (Total Reduced Sulphur), and SO_2 (Sulphur Dioxide).

For TRS, all three sites recorded similar annual averages in 2002 compared to 2001. The Jail recorded the lowest annual average since monitoring began at that site in 1981. The Jail recorded the lowest percent of exceedances of the one-hour and 24-hour Level A objectives since monitoring began at that site. However, TRS levels continue to exceed the one-hour and 24-hour Level B objectives with 25 exceedances of the 1-hour objective recorded at Plaza (downtown) and 35 at the Jail. The TRS levels at the Plaza site exceeded the 1-hour Level A objective about 9% of the time and the Level A 24-hour objective approximately 17% of the time. The number of TRS exceedances of the one-hour Level A objective at the Plaza and Jail sites were higher in 2002 than 2001. In 2002, the maximum number of hours of exceedances during one month at the Plaza was 133 hours (19.7% of the time). Monthly averages ranged from a high of 5.4 $\mu g/m^3$ at Plaza (December) to a low of 0.1 $\mu g/m^3$ at Lakewood (April, May and July).

Annual average levels of SO_2 at all three sites were lower in 2002 than in 2001. CBC site recorded the second biggest incremental decrease in annual averages out of all sites in B.C. that monitored SO_2 in 2001 and 2002. During this monitoring period, there were four exceedances of the ambient SO_2 Level A objective recorded at CBC, with the maximum one-hour average (623 $\mu g/m^3$) occurring in October. Both Plaza and Jail recorded one exceedances of the Level A one-hour objective. Monthly SO_2 averages tend to be the lowest at the Plaza site during spring, but the lowest in October at the Jail and CBC sites. Hourly concentrations tend to be higher at Plaza and Jail during late morning. Hourly concentrations at CBC tend to be high during late morning as well as increasing in the evening until midnight.

The annual average NO_2 level recorded at Plaza in 2002 was the lowest ever recorded at that site. Ambient NO_2 levels were within the provincial Level B hourly and daily objectives since monitoring began at the Plaza site. The highest monthly average occurred in January and the lowest in July in 2002. Monthly averages tend to be higher during late winter and lower during the summer. The annual average recorded at Plaza in 2002 was the lowest annual average ever recorded at that site.

The annual average ozone level recorded at Plaza in 2002 was the second highest ever recorded at that site. But the number of hours of exceedances of the one-hour Level A objective was the lowest since 1997. In 2002, most of the hourly ozone exceedances of the Level A objective occurred in spring. No exceedances of the provincial one-hour Level B objective (160 $\mu g/m^3$) occurred in 2002. Exceedences of the provincial 24-hour Level B objective occurred in ten months in 2002. Plaza recorded the highest number of exceedances of the Level A and B 24-hour objectives in 2002 compared to any other monitored year. Ozone has been gradually increasing in concentration since monitoring began at this site.

2002 showed that there still is a concern with PM_{10} levels meeting the provincial Level B objective. Further reductions in particulate emissions would further reduce the risk of various health effects. Exceedances of the Level B daily PM_{10} objective ranged from 0% (Lakewood) to 7.4% (BCR). Three of the non-continuous monitors recorded higher annual average in 2002 compared to 2001, where as the continuous monitors recorded similar values to the previous year. The highest annual average (22.1 $\mu g/m^3$) was recorded at the BCR site. PM_{10} levels measured with the Lakewood non-continuous monitor recorded the lowest annual average since monitoring began at that site.

Ambient $PM_{2.5}$ levels have been gradually decreasing since monitoring began at the Plaza site with the lowest annual average ever recorded at that site in 1999. Since then $PM_{2.5}$ concentrations have increased. The highest monthly averages in 2002 occurred in November and the lowest in September. Presently the BC Ministry does not have an objective for $PM_{2.5}$.

The priority in the 1998 Prince George Air Quality Plan is reduction of ambient PM_{10} levels. The trend in PM_{10} levels since 1993 indicate that source management actions taken over the past six years have contributed to significantly decreased annual averages at Plaza. While variable atmospheric factors make the analysis of trends causes difficult, over the short term (e.g., dry and hot conditions in the summer of 1998), the overall downward trend in PM_{10}, and in $PM_{2.5}$ levels, very likely reflects the benefits of beehive burner shutdowns, reduced pulp mill emissions from some sources and improved street sanding and spring cleaning. The additional particulate emission reductions included in the Air Quality Plan are needed, however, to continue the trend and to prevent its reversal.

1. PRINCE GEORGE MONITORING NETWORK

In 2002, eight air quality monitoring stations and six meteorological stations were in operation (Figure 1.1). The parameters monitored at each site are listed in Table 1.1. Photographs of most of these locations are including in Appendix F. The PM_{10} monitor at the BCR Engineering Building site was moved to the BCR Warehouse site in July 1996. In April 1997 a temporary mobile unit was installed in the Hart Highlands area near the intersection of Highway 97 North and Austin Road. This unit was on loan to the Ministry from Transport Canada but was returned in March 1998. In June 1998 a new monitoring station was located at Glenview School located approximately 500 metres northeast from the intersection of East Austin Road and Highway 97 North. Monitoring at that site ended in February 2001.

Table 1.1
Prince George Air Quality Monitoring Program for 2002

Site No.	Location	Parameters
0450322	Jail	TRS, SO_2
0450307	Plaza	$PM_{2.5}$, PM_{10}, TRS, NO_x, SO_2, O_3
0450232	Van Bien School	PM_{10}
0450324	Lakewood Jr. School	PM_{10}, TRS
0450270	Gladstone School	PM_{10}
E218771	CNR Site	PM_{10}
E224013	BCR Warehouse	PM_{10}
E209179	CBC Transmitter Site	SO_2
M109912	Plaza	WD, T, RH, SR
M109911	P.G. Pulp	WD, T
M109913	Northwood	WD, T
E224014	Glenview School	WD, T, SR
71908	Airport	WD, T, RH, SR, VIS, CC,PRC, PRS
-	UNBC	WD, T, RH, SR

TRS = Total Reduced Sulphur Compounds (as H_2S)
SO_2 = Sulphur Dioxide
NO_x = Nitrogen Oxides (includes nitric oxide (NO) and nitrogen dioxide (NO_2))
PM_{10} = Particulate Matter less than 10 microns in size
$PM_{2.5}$ = Particulate Matter less than 2.5 microns in size
O_3 = Ozone
T = Temperature
WD = Wind Direction and Wind Speed
SR = Solar Radiation
RH = Relative Humidity
VIS = Visibility
CC = Cloud cover as well as cloud type and ceiling heights
PRC = Precipitation amount and type, including snow on ground
PRS = Barometric Pressure

Figure 1.1

Prince George Monitoring Sites
Glenview
Northwood
Husky
P.G. Pulp
CNR
Intercon
Lakewood
Plaza
Jail
CBC
Van Bien
Airport
UNBC
BCR
1 km
Gladstone
Industrial Sites
Meteorological Sites
Air Monitoring Sites

2. INDUSTRIAL EMISSION SOURCE STATUS

Air quality at any point in time is often determined by a number of factors such as, topography, atmospheric conditions, and the magnitude of emission sources. Variability occurs in atmospheric conditions as well as the rates of emissions discharged from industrial sources. Table 2.1 and Table 2.2 show changes in annual production rates which affect the emission discharge rates from the major industrial sources in Prince George. Productivity was up in 2002 compared to that in 2001 for all three pulp mills, but at the Husky refinery it remained the same. Productivity at Husky, Intercon and Northwood were the highest is has been in the past 12 years.

Table 2.1
Trend in Total Pulp Produced in Pulp Mills since 1990 (Tonnes/day)

	Intercon	P.G. Pulp	Northwood
1990	699	781	1390
1991	685	795	1300
1992	685	785	1410
1993	690	785	1301
1994	730	795	1301
1995	750	790	1415
1996	760	777	1391
1997	788	742	1487
1998	805	759	1499
1999	839	768	1504
2000	836	779	1448
2001	797	732	1342
2002	864	748	1548

Table 2.2
Husky Refinery Annual Average Stream Day Crude Rate
Under Normal Operating Conditions

Year	Average Daily Crude Rate	Percent of Maximum Stream Day Capacity*
1990	1541 m^3	88.1%
1991	1551 m^3	88.7%
1992	1564 m^3	89.4%
1993	1624 m^3	92.9%
1994	1635 m^3	93.5%
1995	1675 m^3	95.8%
1996	1688 m^3	96.5%
1997	1675 m^3	95.8%
1998	1687 m^3	96.5%
1999	1670 m^3	95.5%
2000	1622 m^3	92.7%
2001	1722 m^3	98.5%
2002	1723m^3	98.5%

* Maximum Stream Day Capacity = 1749 m^3

2.1 Total Reduced Sulphur Source Emission Changes

Total Reduced Sulphur (TRS) is a colourless gas with a characteristic offensive odour similar to rotten eggs or rotten cabbage. TRS describes a group of sulphur compounds containing gases made up primarily of one or more of the following four compounds; dimethyl disulphide (DMDS), dimethyl sulphide (DMS), methyl mercaptan (MESH), and hydrogen sulphide (H_2S).

These compounds are largely by-products of the pulping process; that is, these compounds are not added directly but form because of the use of sulphides in the pulping process. Pulp mills using the kraft process emit the largest amounts of TRS followed by oil and gas processing plants (refining) and to a small extent the sewage treatment plant and automobiles (catalytic converters). Natural sources include swamps, bogs, and marshes.

During late 1989 and 1990 there were major modifications performed on emission control systems at all three pulp mills that have affected the rate of TRS and other emissions. At Northwood, steam stripping to reduce the release of TRS gases from the effluent ponds was implemented in November 1989. In December 1991, a new dilute NCG (non-condensable gases) collection system was installed at Northwood.

The pulp mill effluent lagoons were a significant source of TRS emissions but the ambient air quality has shown steam stripping has greatly reduced this source. At Intercon and P.G. Pulp the operation of foul condensate steam stripping, collection and incineration commenced in late 1990. In September 1993, Canfor rebuilt the Intercon recovery boiler, which significantly reduced TRS emissions.

Since 1993, levels of sulphur in the oil feedstock have increased, increasing H_2S emissions from the Husky Oil refinery. The main H_2S source has been the refinery flare, with lesser releases from the bio-oxidation ponds and fugitive emissions from compressor vents, process drains, storage tanks and valves. In 1998, the Husky oil refinery TRS emissions decreased approximately 80% as the result of a sulphur recovery plant being installed in late 1997. The refinery emissions were about 3.4% of the total airshed TRS emissions in 2002 and are much less than from P.G. Pulp and Northwood pulp mills.

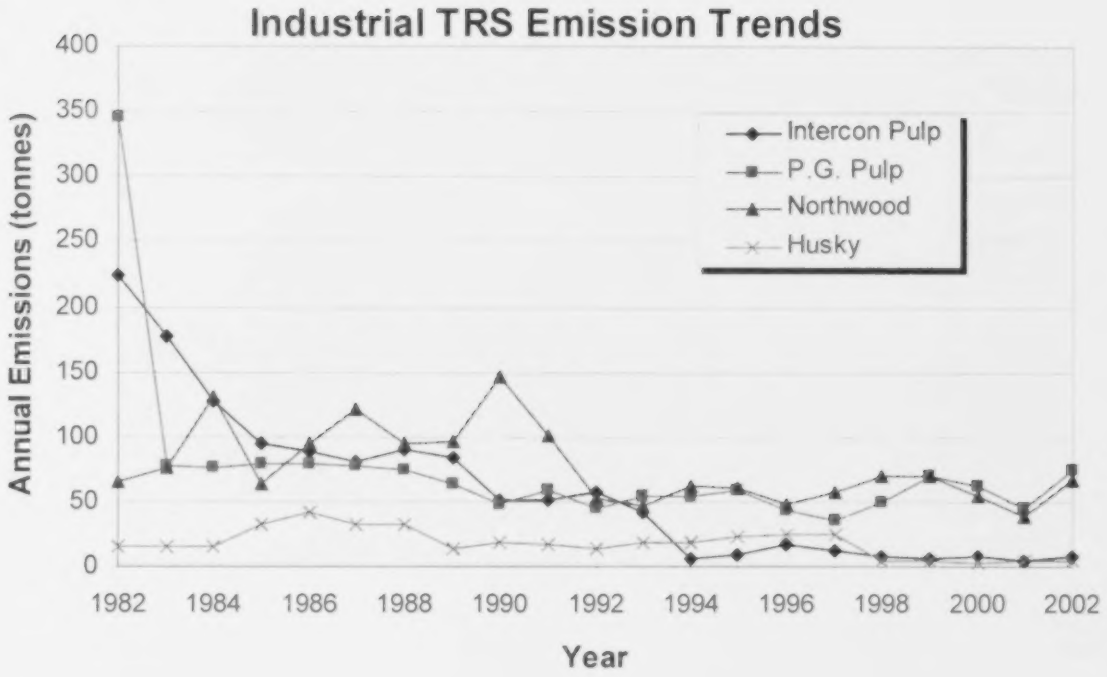
Table 2.3 summarizes annual TRS emission rates (tonnes/year) as estimated under normal operating conditions, from all sources at the pulp mills except the effluent lagoons, which are not regulated. The term "other sources" refers to regulated stack sources at the mill other than the recovery boiler. These sources include: black liquor oxidation systems, dissolving tanks, lime kilns, filtrate tanks, slaker stack, brown stock washing stack, and chip bin.

Table 2.3
Summary of Annual TRS Emissions (as H_2S) from the Three Pulp Mills and Husky Oil Refinery Under Normal Operating Conditions (Tonnes per Year)

Year	Husky	Intercon Pulp		P.G. Pulp		Northwood		Pulp mill		Total
		Rec. Boiler	Other Source	Rec. Boiler	Other Source	Rec. Boiler	Other Source	Rec. Boiler	Other Source	For all Sources
1980	-	557.1	120.9	1010.5	65.7	77.5	152.4	1645.1	339.0	>1984.1
1981	-	93.3	219.4	910.6	59.1	48.6	73.6	1052.5	352.2	>1404.7
1982	16	68.3	156.4	262.8	82.8	15.8	49.9	346.9	289.1	652.0
1983	16	85.4	92.0	23.7	53.9	11.8	64.4	120.9	210.2	347.1
1984	16	61.8	65.7	11.8	64.4	14.5	115.6	88.0	245.7	349.8
1985	32	26.3	68.3	13.1	65.7	21.0	43.4	60.4	177.4	269.8
1986	42	31.5	57.8	10.5	68.3	15.8	78.8	57.8	205.0	304.8
1987	32	26.3	54.7	15.2	62.0	26.3	94.6	67.8	211.3	311.1
1988	32	29.9	59.9	16.8	58.3	33.6	61.5	80.4	179.8	292.2
1989	14	31.5	52.6	11.6	52.6	11.0	86.2	54.1	191.3	259.5
1990	18	31.5	20.0	13.1	35.2	65.2	80.9	109.9	136.1	264.0
1991	17	31.5	20.0	15.8	43.1	26.3	74.1	73.6	137.2	227.8
1992	14	36.3	21.0	14.7	30.5	27.9	24.7	78.8	76.2	169.1
1993	19	28.4	13.1	15.8	39.4	21.0	26.3	65.2	78.8	163.0
1994	19	5.8	1.1	14.7	40.5	31.5	31.5	52.0	73.1	144.1
1995	24	4.7	4.2	12.6	47.3	33.1	27.3	50.4	78.8	153.2
1996	25	3.7	13.7	10.5	32.6	27.9	20.5	42.1	66.8	133.9
1997	25	4.7	8.4	9.5	26.8	30.5	26.8	44.7	62.0	131.7
1998	5	3.7	4.7	11.0	38.9	34.2	36.3	48.9	79.9	133.8
1999	4.7	4.2	1.6	17.9	52.0	31.5	37.8	53.6	91.4	149.7
2000	3.2	4.7	2.6	17.9	44.2	27.9	26.8	50.5	73.6	127.3
2001	4.5	3.2	1.2	13.8	31.5	19.4	20.0	36.4	52.7	93.6
2002	5.2	6.8	1.1	16.3	58.3	33.1	34.2	56.2	93.6	155.0

Emissions from "other sources" are calculated based on samples taken at the sites once per month. The annual emissions depend mainly on emission rates and mill output, and may vary slightly depending on whether a monthly sample is representative for that particular month. Overall TRS emissions from Intercon in 2002 were the highest recorded in the past four years at that site. At P.G. Pulp the recovery boiler emissions in three of the past four years were the highest since 1988. The big increase since 1999 in P.G. Pulp's recovery boiler emission rate is from burning more liquor in their recovery boiler as well as the gradual increase in production. TRS emissions from Northwood Pulp were the highest recorded since 1999 at that site. Pulp production (Table 2.1) increased at the three pulp mills in 2002 from the previous year, and was the highest at the Intercon and Northwood mills in the past 12 years. The overall total TRS released by the three pulp mills was the highest recorded since 1992 and increased approximately 68% from last year. Figure 2.1 shows the plotted annual TRS emissions for all three pulp mills and the Husky oil refinery.

Figure 2.1



2.2 Sulphur Dioxide Source Emission Changes

Sulphur Dioxide (SO_2) is a colourless gas that has a pungent odour at concentrations above 900 $\mu g/m^3$ (Level B one-hour objective).

SO_2 is formed primarily by the combustion of material containing sulphur. At present, the major sources of SO_2 in the Prince George area are the Husky refinery and the three pulp mills. Minor sources include the Marsulex sulphuric acid plant and the railways (Prince George Airshed Technical Management Committee, 1996). Other anthropogenic sources (i.e., residential and commercial space heating) and natural sources (i.e., long range transport of SO_2 from volcanoes and swamps) are very small compared to the emissions produced by the industries.

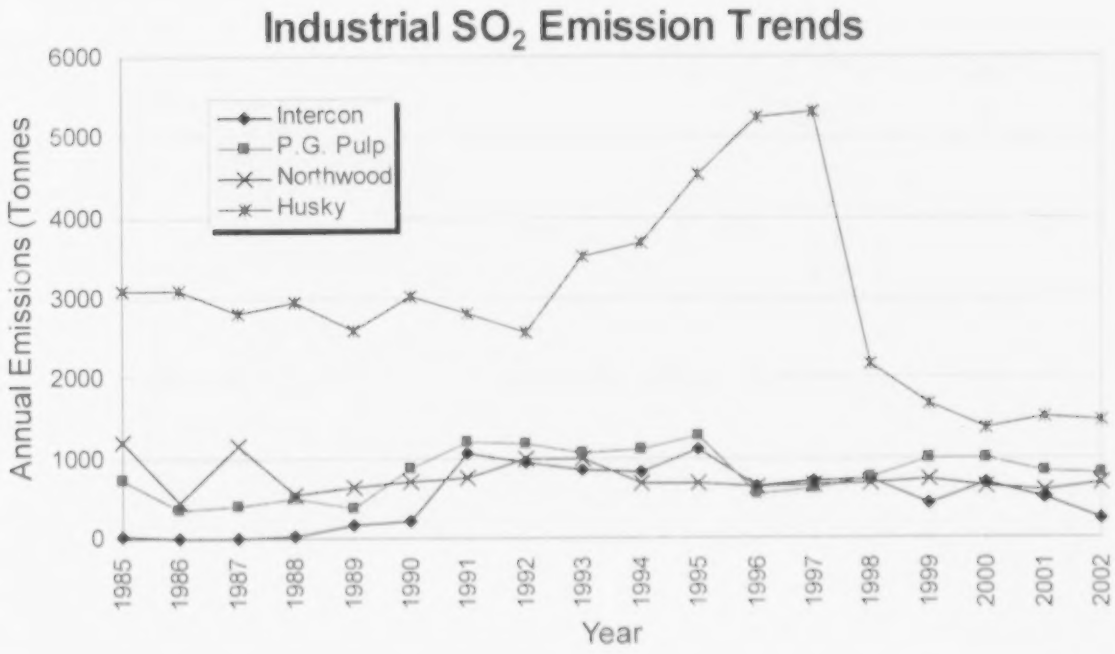
At all three pulp mills, most of the SO_2 is emitted from the incinerator stacks. The SO_2 emission rate in 2002 from Intercon Pulp was the lowest recorded since 1990, as shown in Table 2.4 and Figure 2.2. Intercon's SO_2 emissions are about 25% of what was emitted in 1991-1995. P.G. Pulp's emission rate was lower than the previous three years. The decrease in emission rate at P.G. Pulp after 1995 was due to a recovery boiler upgrade in 1996 which gave it a higher solids firing temperature. The emission rates at Northwood were higher at that site than that in 2000 and 2001.

A sulphur recovery unit started operation at Husky Oil on November 20, 1997. This unit was expected to reduce SO_2 emissions from Husky's flare by as much as 75%. SO_2 at Husky is emitted mainly from the flare, FCC regenerator stack, foul water stripper, process heater stacks and sulphur recovery incinerator stack. Almost 67% of the SO_2 emissions are from the regenerator stack. Another 22% was from the Refinery Flare, 6% from the sulphur recovery incinerator stack, and 5% from the foul water stripper. Husky's SO_2 emissions were somewhat lower in 2002 than 2001 and approximately 73% lower than in 1997.

Table 2.4
Summary of Annual SO_2 Emissions from the Three Pulp Mills and Husky Oil Refinery Under Normal Operating Conditions (Tonnes per Year)

Year	Intercon	P.G. Pulp	Northwood	Total Pulp Mill	Husky	Total
1985	31.5	735.8	1208.9	1976.3	3101.0	5077.3
1986	10.5	352.1	452.0	814.7	3085.3	3900.0
1987	11.0	403.1	1156.3	1570.5	2801.4	4371.9
1988	15.2	505.6	536.1	1057.0	2953.9	4010.9
1989	168.2	381.1	641.2	1190.5	2610.1	3800.6
1990	212.9	879.9	704.3	1797.0	3016.9	4814.0
1991	1058.0	1200.5	760.5	3019.0	2813.5	5832.6
1992	942.9	1174.7	983.4	3101.0	2563.9	5664.9
1993	840.0	1072.2	982.9	2895.0	3515.2	6410.2
1994	838.3	1102.2	683.3	2623.8	3679.2	6303.0
1995	1114.3	1275.6	683.3	3073.2	4541.7	7614.9
1996	630.2	541.6	636.0	1807.8	5246.5	7054.3
1997	716.4	614.9	651.7	1983.0	5323.3	7306.3
1998	726.9	766.3	675.4	2168.6	2161.8	4330.4
1999	424.6	985.5	725.3	2135.4	1669.3	3804.7
2000	682.8	983.9	636.0	2302.7	1367.1	3669.8
2001	493.0	824.0	588.7	1905.7	1505.3	3411.0
2002	239.1	811.0	680.1	1730.2	1460.1	3190.3

Figure 2.2



2.3 Total Particulate Source Emission Changes

Particulate matter refers to small particles ranging in size from 100 μm to 0.001 μm (micrometres) (1,000,000 μm =1 m). Particles range in chemical composition, size, shape, and physical properties. The sources in Prince George can range from natural sources such as pollen and dust from soil erosion, and from man-made sources such as soot, flyash, and smoke.

Table 2.5 identifies the total particulate emissions in 2002 from the three main pulp mill sources; the recovery boiler, power boiler, and the lime kiln/dissolving tank, as provided by Canfor. Only P.G. Pulp met their permit requirements in 2002 for particulate emissions from all the sources mentioned based on quarterly stack sampling. Northwood had to resample once for one of their Dissolving Tanks, and Intercon resample once for their Lime Kiln both due to high levels recorded during one quarterly sample. Due to upgrades of the boilers at Intercon, most of the particulates emitted in 2002 were from the lime kiln and dissolving tanks with only 25% from the recovery boilers, whereas, at PG Pulp about 60% of the particulates were emitted from the recovery boiler. Particulate emissions from the recovery boiler were twice as high as those from the power boiler at P.G. Pulp. At Northwood, the particulate emissions from the power boiler were similar to that from the recovery boiler.

Table 2.5
2002 Particulate Emission Rates from the Pulp Mills (kg/min)

Pulp Mill	Recovery Boiler	Power Boiler	Lime Kiln & Dissolving Tank	Total
Intercon Pulp	0.112	0.040	0.215	0.367
P.G. Pulp	0.874	0.391	0.155	1.42
Northwood Pulp	0.907	0.903	0.417	2.227

Note: These rates represent normal operating conditions

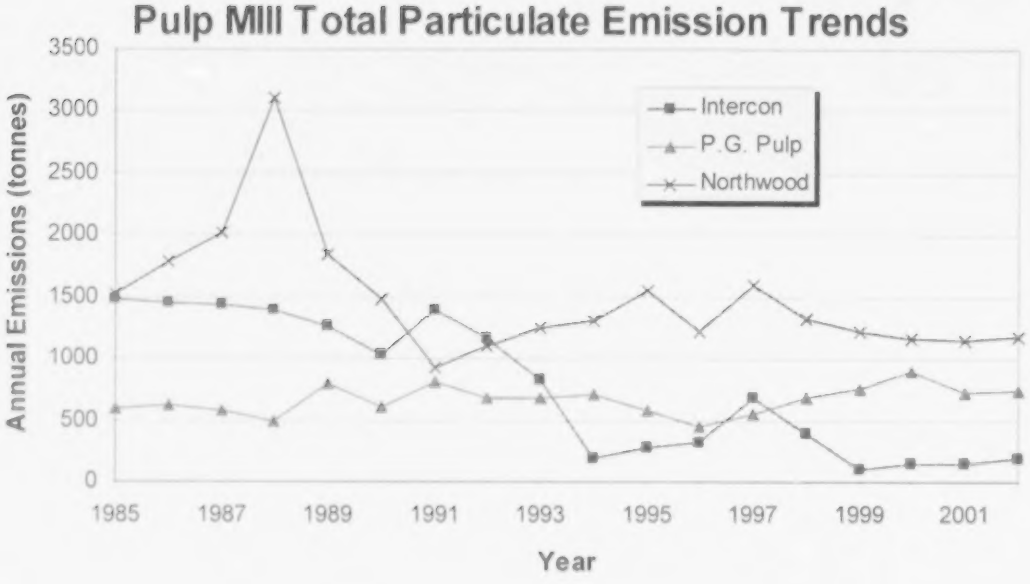
Total particulate emissions are listed in Table 2.6 and Figure 2.3 for the three area pulp mills based on emission testing under normal operating conditions. Particulate emissions in 2002 from all three pulp mills increased from the previous year (Table 2.6). Total particulate emissions from Intercon in 2002 showed the biggest increase relative to 2001, but still only about 14% of the average annual total particulates emitted in 1985-1987 from that site. In 1997 there was a dramatic increase at the Intercon pulp mill that was due to a combination of increased production and the amount of hog fuel being fired for power production. The decrease in 1999 was due to a new precipitator installed on the power boiler.

The 1994 decrease at Intercon Pulp was due to the re-building of the recovery boiler in 1993. A new precipitator chamber on the #1 recovery boiler at Northwood Pulp in late 1990 greatly reduced emissions in 1991, but emissions gradually increased over the next few years. The increase in emissions at Northwood was due to the recovery boiler taking several years to gradually operate to full potential after the upgrade.

Table 2.6
Summary of Annual Total Particulate Emissions from the Three Pulp Mills
Under Normal Operating Conditions (Tonnes per Year)

Year	Intercon	P.G. Pulp	Northwood	Total
1985	1482.2	599.2	1519.0	3600.4
1986	1450.7	625.5	1787.0	3863.2
1987	1430.7	586.0	2023.6	4040.3
1988	1394.4	491.4	3101.0	4986.8
1989	1266.2	797.3	1849.6	3913.1
1990	1037.0	603.9	1476.9	3117.8
1991	1387.1	813.1	930.3	3130.5
1992	1157.9	680.7	1102.7	2941.3
1993	829.9	680.1	1250.9	2760.9
1994	191.3	706.4	1308.7	2206.4
1995	282.2	577.6	1561.0	2420.8
1996	318.5	446.2	1219.4	1984.1
1997	676.4	547.2	1592.6	2816.2
1998	398.4	687.5	1327.7	2413.6
1999	104.1	748.5	1226.8	2079.4
2000	149.3	898.8	1162.1	2210.2
2001	141.9	720.1	1141.6	2003.6
2002	192.9	746.4	1170.5	2109.8

Figure 2.3



Sawmills and their wood waste burners, as well as road dust, are other major sources of particulate and contribute significant loading to the airshed, as indicated by the 1995 emission inventory (Prince George Airshed Technical Management Committee, 1996). Wood waste burners in the Prince George airshed have being phased out with the last burner in the airshed shutting down at the end of 2000. Particulate emissions are not measured at sources other than the pulp mills and North Central Plywood, so no trends can be assessed on these other sources. Emissions of road dust, have not been measured, but have been estimated to be potentially significant PM_{10} sources seasonally. A thesis submitted to the University of Northern British Columbia (Breed, 1998) examined the origin of fine particulates during three episodes in 1995 and 1996. The February and March episodes had significant dust contributions to ambient PM_{10} levels, while the January episode had a significant non-dust component.

The City, the Regional District of Fraser-Fort George and the Ministry of Water, Land and Air Protection finalized an air quality management plan in 1998 that addresses the significant particulate sources, including industrial, residential, and mobile sources. Methods to evaluate the effectiveness of non-industrial emission reductions are included in the plan. The city has carried out various measures to reduce the dust from winter street sanding. In 1997 screening of traction material to remove the silt portion was started. In 2000, the city began adding salt to the street cleaning liquids to enable cleaning to start before streets were completely dried out.

A reduction of open burning of wood residues is also expected to help to reduce the loading of particulate to an airshed that often has a limited capacity to disperse pollutants. The City of Prince George has achieved a reduction in the amount of open burning from commercial land clearing. Homeowners are being encouraged to reduce burning of yard waste by composting, and bins have been placed at two locations for collection of compostable material (at the Foothills Landfill and at Munro Street). There are also bins placed at eight locations in Prince George for collection of cardboard and newspapers. In spring and fall there are additional bins for the collection of compostables placed around the city. Contact the Regional District of Fraser Fort George at 960-4483 for the location of these bins.

In 2001, City Council passed a Clean Air Bylaw which sets requirements for achieving additional reductions in smoke and dust emissions. Measures included a ban on open burning, including yard wastes and land clearing debris, within the Fraser and Nechako River valleys, and a ban on non-essential woodstove and fireplace wood burning during air quality advisories.

Other anthropogenic particulate emission sources include woodstoves, fabricating shops, incinerators, internal combustion engines, auto body shops, and mobile exhaust sources (road and rail emissions). Since these sources are not monitored directly, like the pulp mill sources, their contributions to overall particulate emissions was estimated using emission inventories.

3. METEOROLOGICAL INFORMATION FOR 2002

During 2002, four Meteorological Information Stations (MIS) were operated by the Ministry of Water, Land and Air Protection, in addition to the federal meteorological station located at the airport, and a monitor operated by the University of Northern B.C. (UNBC) which is located on the roof of the university building. These stations are listed in Table 3.1 showing their locations, elevations and the percent of valid data recovered over the past year. Data recovery ranged from 99.6% (UNBC) to 99.9% (Airport, Hart and Northwood).

Table 3.1
2002 Meteorological Stations with Percent Valid Data

Station Name	Latitude (deg/min/sec)	Longitude (deg/min/sec)	Elevation (metres)	Percent of Valid Data
Plaza	53 54 48	122 44 28	595	99.7
Northwood	53 58 03	122 41 27	577	99.9
P.G. Pulp	53 55 28	122 41 10	600	99.7
Hart	53 59 44	122 46 32	750	99.9
Airport	53 53 20	122 40 30	691	99.9
UNBC	53 53 43	122 48 52	814	99.6

Hourly averages for wind direction, wind speed and temperature are measured at the meteorological stations listed, except for the Airport station where all hourly archived data consist only of the values recorded about five minutes before each hour. Solar radiation is also monitored at the Plaza and UNBC sites. Relativity humidity is recorded at the Plaza, Hart, and Airport sites. At the Airport site, Environment Canada also monitors cloud type and cover, precipitation amounts, snow on the ground, visibility, and barometric pressure.

Since September 2001 all anemometers used in the Prince George airshed are the RM Young (Fig. 3.1). The RM Young is the more sensitive instrument and has a much lower starting threshold than the older Gill Microvane/3-Cup that were originally located at the ministry's meteorological stations. In order to compensate, an adjustment of 0.45 m/s was added to all scalar wind speeds at all sites that use the Gill instrument. No adjustment is needed for the RM Young instruments. This adjustment produced a higher frequency of calm winds at those sites that used the RM Young instrument. At the Plaza and the P.G. Pulp sites the Gill anemometers were replaced by RM Young monitors in May 2000. The Gill anemometers were replaced at Northwood in August, 2001 and at Hart in September, 2001.

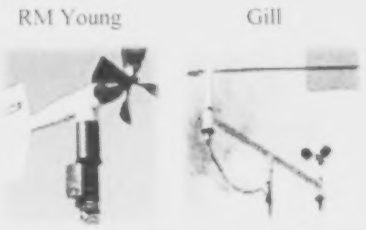


Fig. 3.1 Anemometers used in Prince George Monitoring Program

3.1 Analysis of Winds

Figures 3.2 to 3.7 show the wind direction frequencies at each of the 16 major compass points, and the average wind speed in each direction at the six meteorological stations (wind direction refers to the direction from which the wind is blowing). For example, at Northwood, winds from the south occurred about 13% of the time. All sites showed a high frequency of winds (at least 11%) from the south and, with the exception of the Plaza site all sites showed a low frequency of winds (<2%) from the east. The frequency of calms from the three sites located in the valley ranged from 17.3% – 17.7%. Calms winds recorded at the two sites located at the higher elevation ranged from 16.2% - 16.4%. The Airport site which uses an instrument that is less sensitive to low wind speeds recorded a 23.8% frequency of calms.

The frequency distribution of wind directions at Northwood (Fig. 3.2) shows a classic valley-type flow with the wind directions being predominately southerly or northerly, in line with the valley. The frequency distribution at P.G. Pulp (Fig. 3.3) still shows the north-south valley flow but not as marked as at Northwood. The effect of the expansion of the valley into the larger bowl area is noted on the wind patterns at P.G. Pulp with stronger and more frequent southwest to west winds. Light winds from the north occurred more frequently than those from the south at Northwood and P.G. Pulp in 2002. This is due to down valley winds that occur at night or during winter and are normally less than 2 m/s. The increased frequency of northerly winds is due to the drainage effect. At night, winds are known to diminish as the air cools. The cooler air, which is heavier than warmer air, sinks and moves down the valley, resulting in the higher frequency of light northerly winds. Valley sites detect this northerly flow, but sites on top of the plateau may report calm winds or light winds from another direction.

At Northwood, the frequency of stronger winds (> 6 m/s) from the south were similar to those from the north. At P.G. Pulp, the frequency of stronger winds from the south is much higher than those from the north. West winds greater than 6 m/s are also more frequent than the north winds even though the overall frequency of north winds was two times higher than that of the west wind. The high frequency of strong winds from the south and west were due to the geostrophic flow over the area normally being from those sectors.

At Plaza (Fig. 3.4), the north/south valley effect is not so predominant. Although south is still the dominant direction, there are more east than north winds. This occurs because north winds are deflected eastward by the hills located south of the pulp mills, before reaching the Plaza monitoring site. In fact, most of the east winds are light; < 4 m/s. The stronger winds tend to occur in all sectors except from the east and the southwest sectors. The low frequency of strong winds from the southwest is probably due to the air flow from that direction being blocked by Connaught Hill which is located about 200 metres directly southwest of the monitor.

Figure 3.2 Wind Rose for Northwood Meteorological Station for 2002

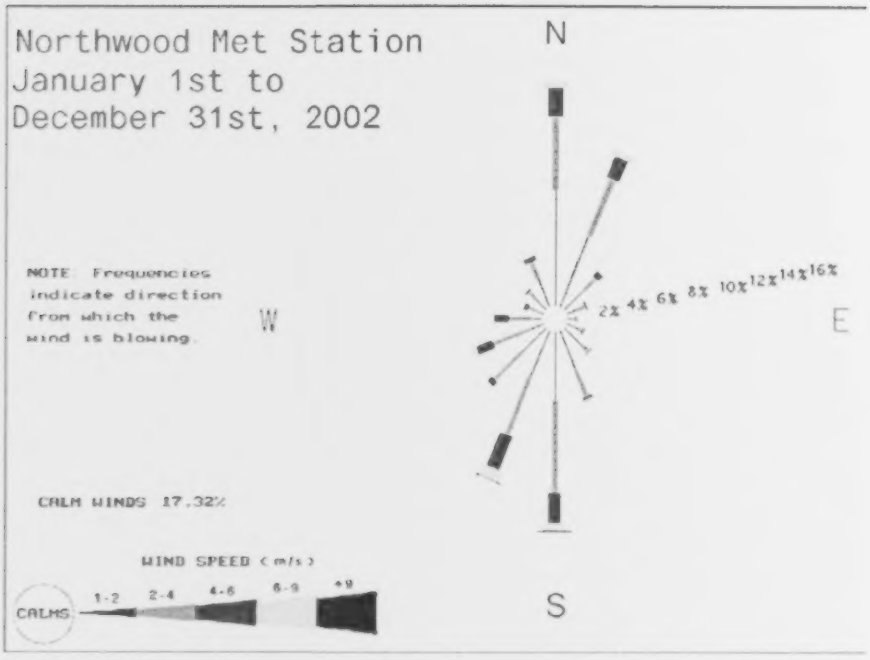


Figure 3.3 Wind Rose for P.G. Pulp Meteorological Station for 2002

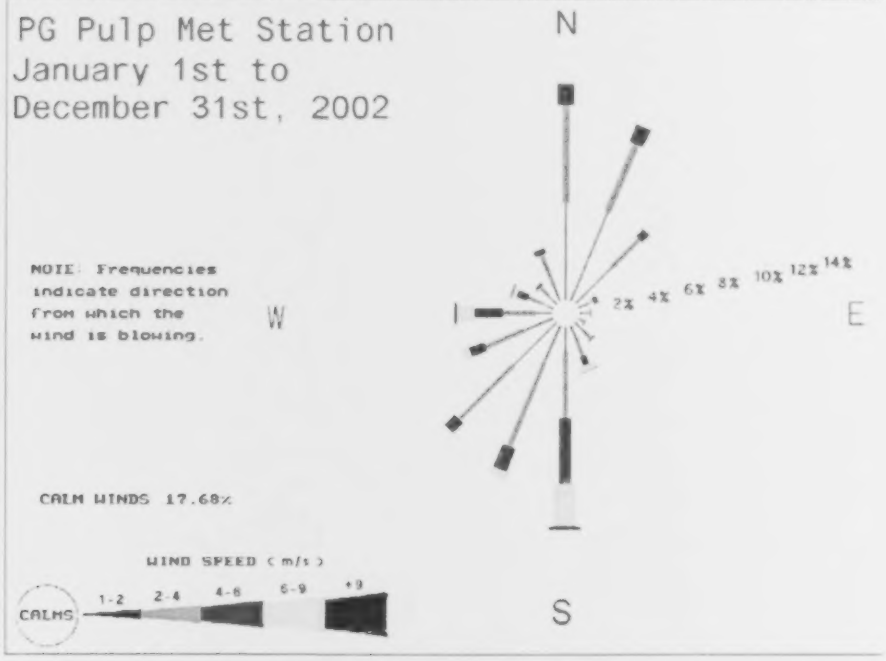


Figure 3.4 Wind Rose for Plaza Meteorological Station for 2002

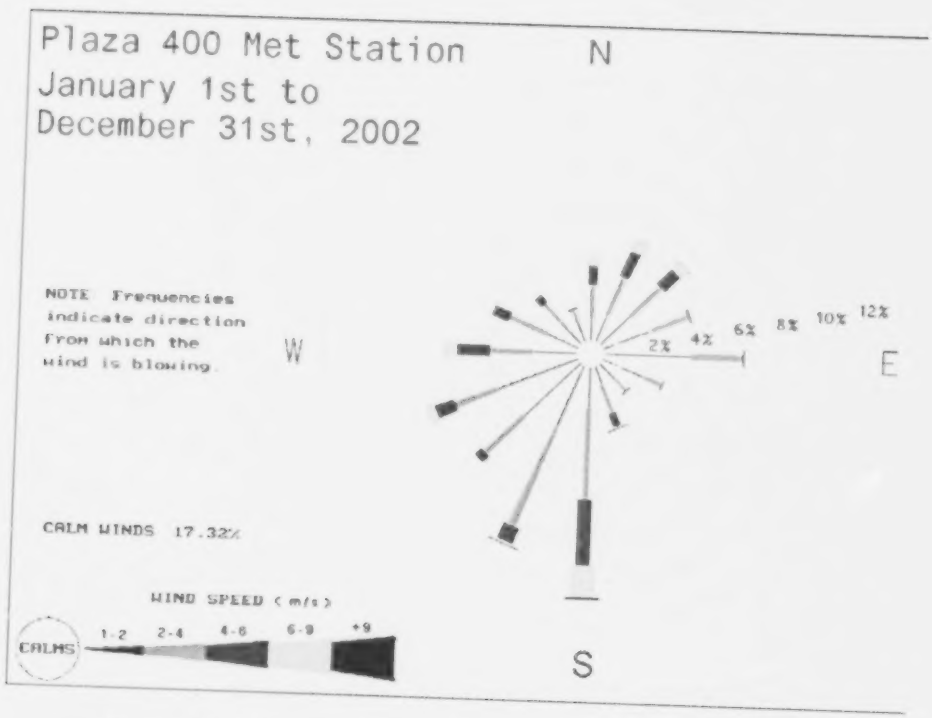


Figure 3.5 Wind Rose for Hart Meteorological Station for 2002

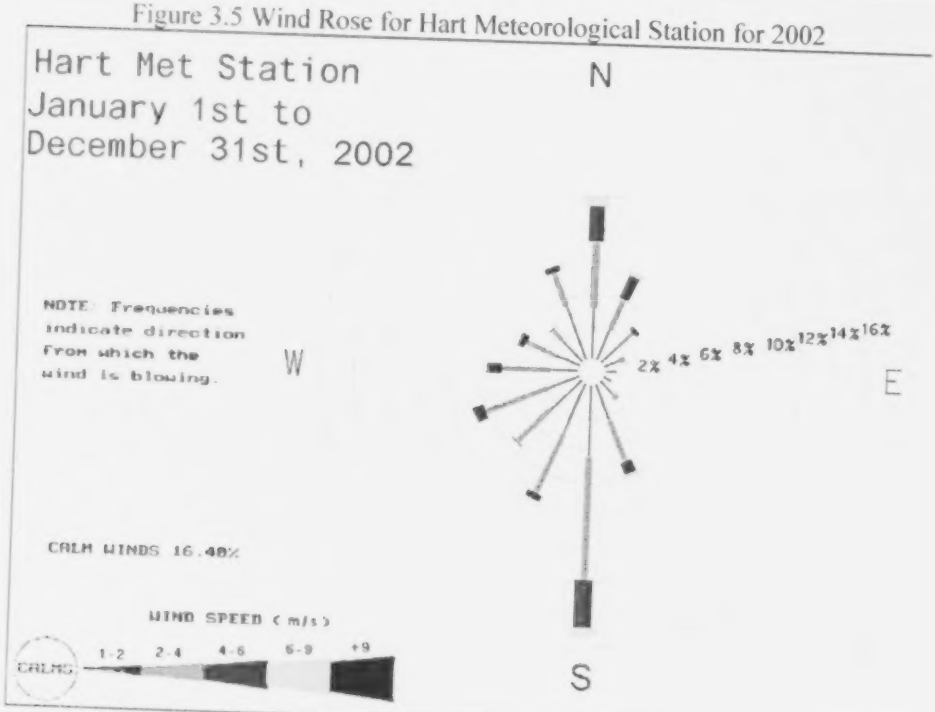


Figure 3.6 Wind Rose for Airport Meteorological Station for 2002

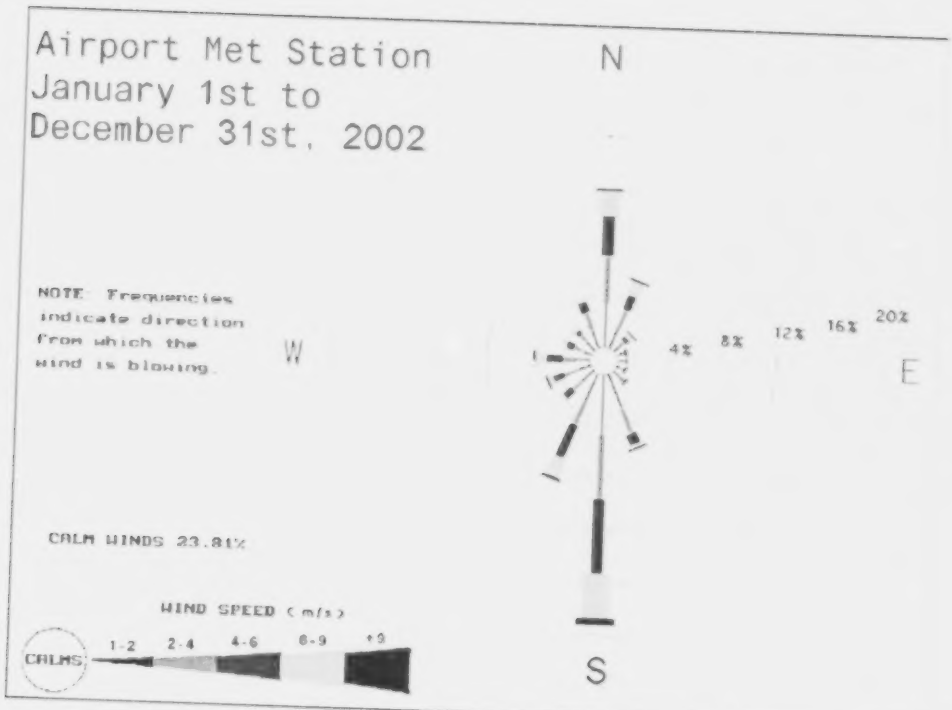
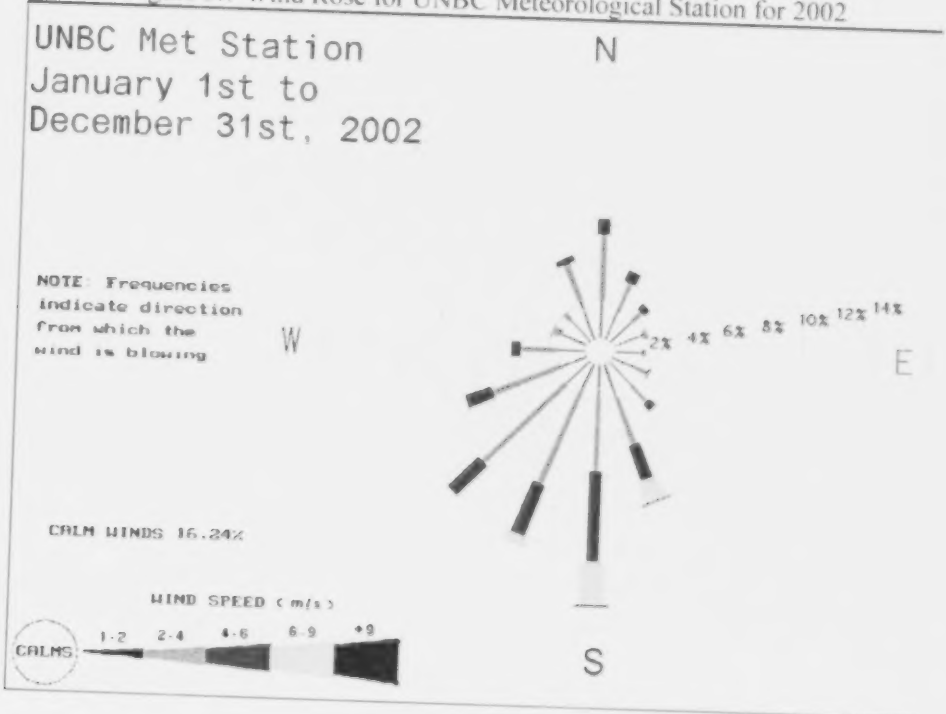


Figure 3.7 Wind Rose for UNBC Meteorological Station for 2002



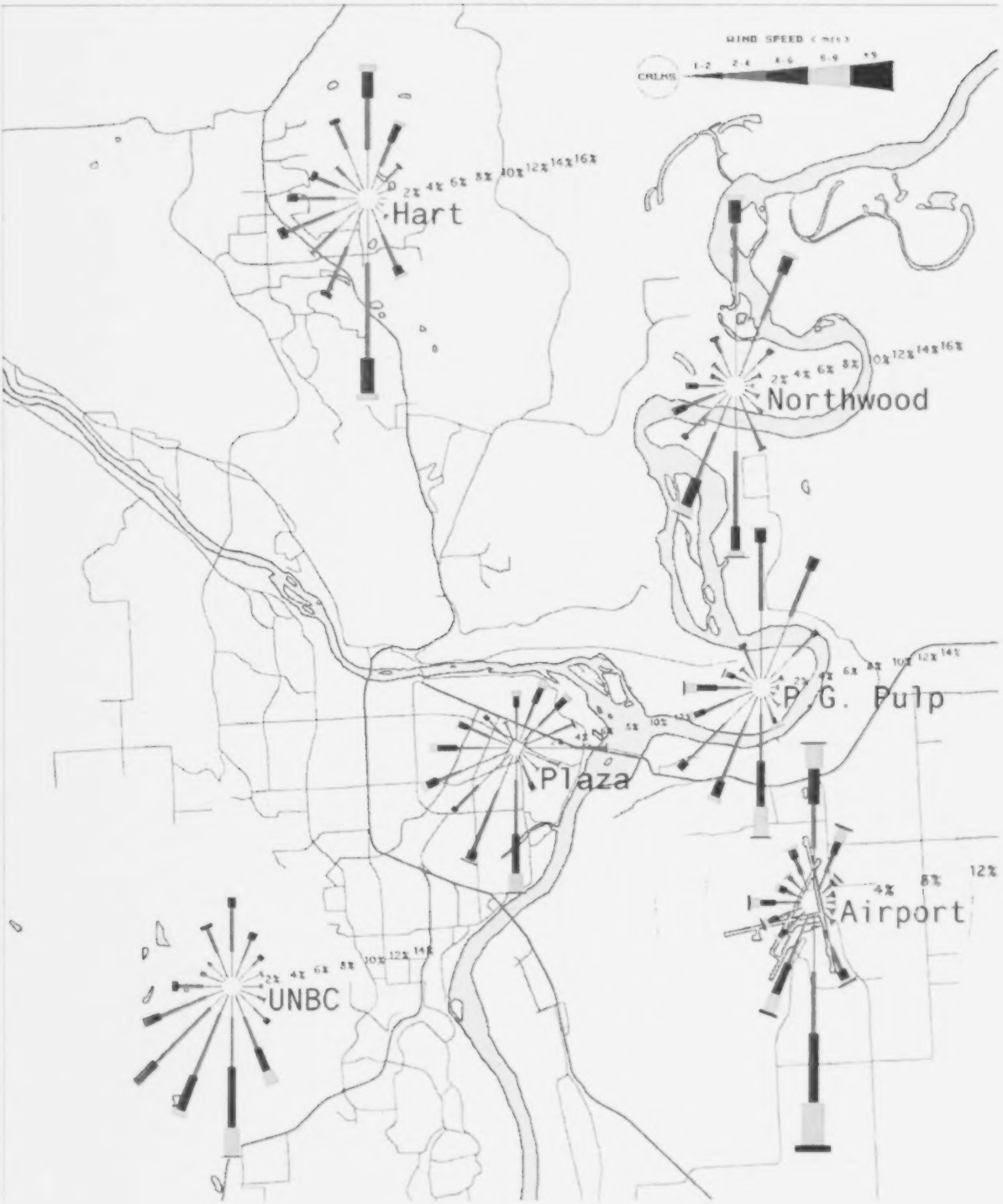
The Hart site (Fig. 3.5) also shows the terrain influence on air flow. Unlike the Northwood and P.G. Pulp sites, the frequency of wind direction is higher from the south compared to that from the north. The lower frequency of northerly winds at the Hart site compared to Northwood and P.G. Pulp sites shows that because of its elevation, there is less of an influence from the terrain features, compared to the valley sites. As previously mentioned, when valley sites are showing a northerly flow, sites on top of the plateau may report calm winds or light winds from another direction. The stronger winds (> 6 m/s) at the Hart site seems to occur from the northerly and southerly directions. Winds from the east rarely occur at this site.

The Airport data shows the frequency for southerly winds to be over 50% higher than that for northerly winds (Fig. 3.6). The wind rose is similar to that at the Hart station, but with a slightly lower frequency of winds from the east and west. There is a higher frequency of stronger winds (> 4 m/s) from the north and south directions at the airport compared to those at the Hart. The Airport may be subjected to more of a valley effect than the Hart, because the Hart is located about 70 metres higher in elevation. Winds greater than 6 m/s occurred from almost all directions at the Airport. There was a higher frequency of calm winds (23.8%) recorded at the airport compared to the other sites. This could be due to the instrument used at the airport being less sensitive than those used at other sites, which may also be the reason for the much higher frequency of north and south winds.

The UNBC meteorological site is located at the highest elevation and is over 200 metres higher than the three sites in the bowl. Again there is a higher frequency of south winds which may be due to the general synoptic pattern over the area. However, the frequency of north winds is lower at this site, probably due to less effect from the flow moving down the valley. Winds greater than 4 m/s mainly occurred from the southeast to southwest sectors and rarely from the east. Light winds from the north seem to occur as frequent as those from the south and slightly higher than those from the east and west sectors. This is another indication of elevated sites being less affected from the down valley flow due to the drainage effect.

Figure 3.8 shows the direction frequency distribution (wind rose) plotted on a map of the Prince George area. The effect of the valley is apparent in the distribution of wind directions at each station.

Figure 3.8: Map of Prince George Showing the Six Wind Roses for 2002



Of greater importance to air quality, Figures 3.9 and 3.10 show the frequency distribution of directions when the wind speed is less than 1 m/s and between 1 m/s and 2 m/s, respectively. Light wind speeds are usually associated with inversion conditions, which result in poor dispersion of pollutants. It is significant to note that at P.G. Pulp and Northwood, winds less than 1 m/s occurred from the north at least 38% of the time. Under these conditions and because of the curvature of the Fraser River valley between P.G. Pulp and downtown Prince George, TRS from the low-level sources at the mills is transported directly downtown. This is confirmed by the high frequency (33%) of light easterly winds at Plaza. Data for the airport are not shown in Figure 3.9 because no wind direction is provided for wind speeds <1 m/s.

Figure 3.9

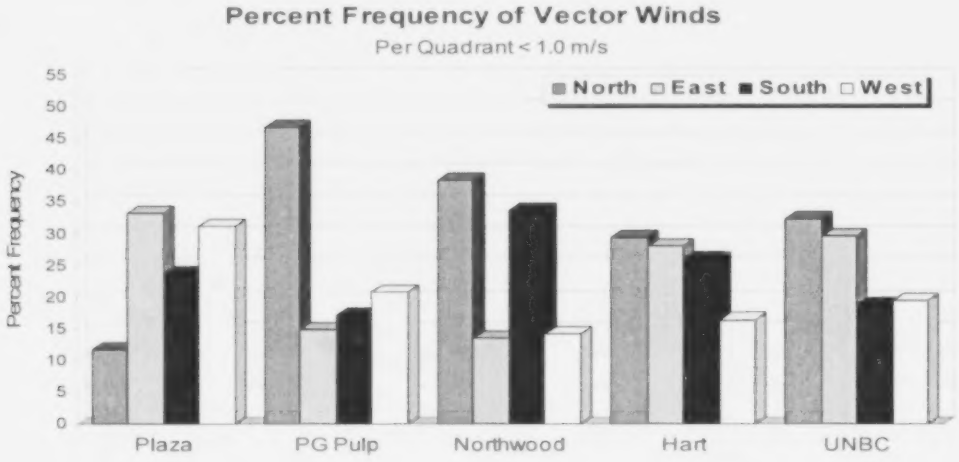
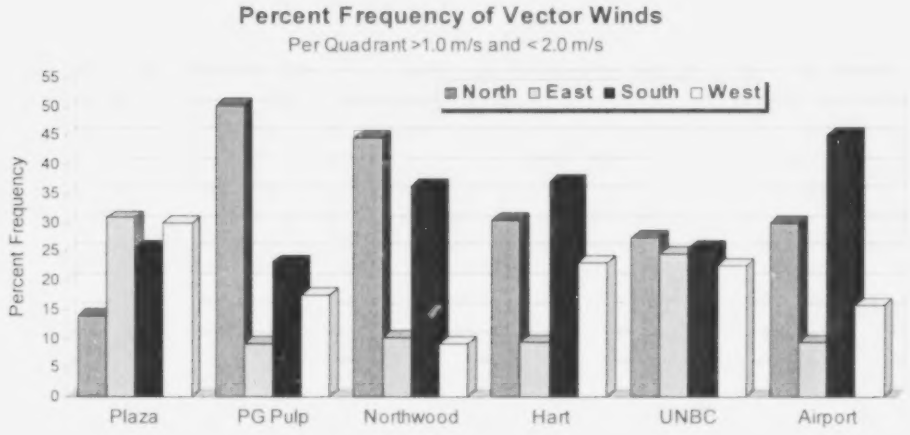


Figure 3.10



There was a higher frequency of northerly winds < 1 m/s at UNBC (32%) compared to southerly winds (18%). This contrasts with the overall distribution of winds in Figure 3.7, in which winds from the south occurred about twice as frequently as those from the north. This is an indication of the stronger influence of the valley channelling on light winds. Other sites showed a similar pattern but not as noticeable as that at UNBC. Also, for winds between 1-2 m/s at UNBC the frequency distribution for north winds is similar to that for south winds.

Analysis of data from the six stations makes it apparent that winds can be channelled along the valley resulting in wind directions similar to the orientation of the valley. The percent frequencies per quadrant of vector wind speeds less than 1.0 m/s were slightly different from the frequencies of 1.0 m/s to 2.0 m/s wind speeds. This difference may be due to the terrain effect dominating the wind direction during light wind conditions, and to the greater influence of synoptic flow on wind direction when wind speeds are 1.0 to 2.0 m/s.

A higher percent of north winds less than 1.0 m/s occurred at the Northwood and P.G. Pulp stations (valley sites) compared to the Hart and UNBC (higher elevation sites). All four sites showed higher frequency of light winds (<1 m/s) from the north, but for winds between 1 and 2 m/s the frequency of south winds were higher at the Hart and about the same at UNBC. At night, winds are known to diminish as the air cools. The cooler air, which is heavier, sinks and moves down the valley, resulting in the higher frequency of northerly flow at night at these sites.

Figure 3.11

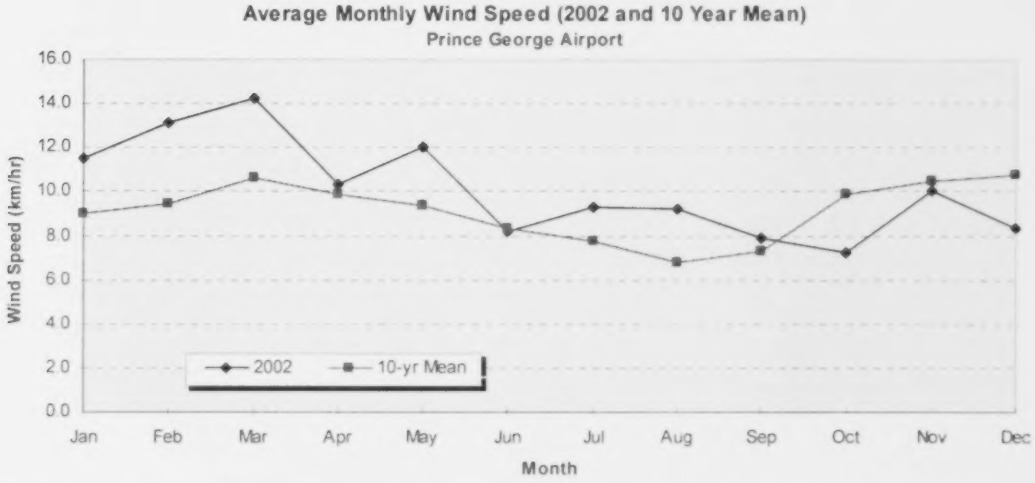
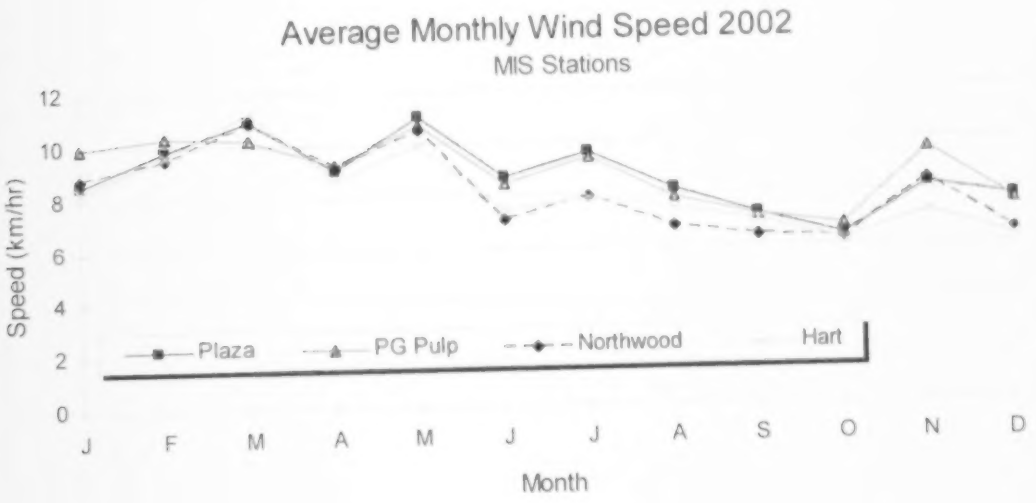


Figure 3.11 shows the monthly average 2002 wind speeds from the Prince George airport compared with the 10 year average (1992-2001). Six months had average wind speeds substantially higher than the 10-year monthly mean. Only October and December were substantially lower than the 10-year mean. Overall, the average annual wind speed was higher than the 10-year mean.

Figure 3.12 shows the monthly average wind speed at the four MIS stations. The same monthly trend in the airport data is apparent at the MIS stations. It is noticeable that the average wind speed at the P.G. Pulp site was higher than that at the Plaza site during the winter (Nov. – Feb.) and slightly lower during the summer (May – Aug.). Northwood had the lowest wind speeds during the summer (June – Sept.), but the Hart had the lowest wind speed during the winter.

Figure 3.12



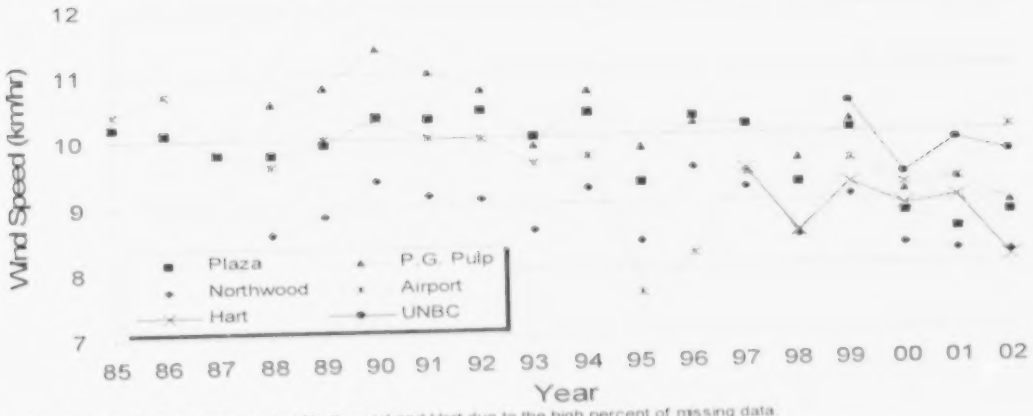
3.1.1 Wind Trends

Figure 3.13 shows annual trends in wind speeds that are similar at all sites except for lower values at the airport in 1995 and 1996. The airport differences could have been due to the deterioration of the monitor at that time. Because the instruments were replaced at the four MIS station in 2000 and 2001, it is now not possible to determine a trend for those years at these sites. All sites showed a decrease in 2002 compared to 2001 except for the Airport and Plaza sites. Average wind speeds at the Hart before 2000 and in 2002 were lower than those at the Plaza, but were higher than at the Plaza in 2001. This was due to the meteorological instrument at Plaza being switched to a RM Young instrument in May 2000, whereas the instrument at the Hart was not replaced until September 2001.

Meteorological factors such as synoptic scale phenomena (frontal passage, movements of high and low-pressure regimes), and cloud cover affect wind flow. Higher wind speed generally produce better air quality, depending on wind direction. A clear sunny day normally would produce more daytime mixing and stronger winds than clear skies at night with temperature inversions and calmer winds. Also, on clear nights, radiation cooling causes air to sink and move down the valley resulting in a higher frequency of light northerly winds in Prince George.

Figure 3.13

Annual Mean Wind Speed Trend



* Wind speeds for 2001 estimated at Northwood and Hart due to the high percent of missing data.

3.2 Analysis of Precipitation

Precipitation plays an important role in air quality. Not only does rain wash pollutants out of the air, but also prevents dust from being emitted into the airshed. Water droplets can also contribute to faster chemical reactions of pollutants.

Figure 3.14 shows the monthly total precipitation recorded at the airport compared to the 10-year average (1992-2001). Precipitation was significantly above the ten-year average for September, and somewhat higher in March and April. Considerably lower relative precipitation amounts were recorded in seven months in 2002. The precipitation in December was one of the lowest ever recorded for that month.

Figure 3.14

Comparison of Total Monthly Precipitation at the Airport Between 2002 and the 10-Year Average

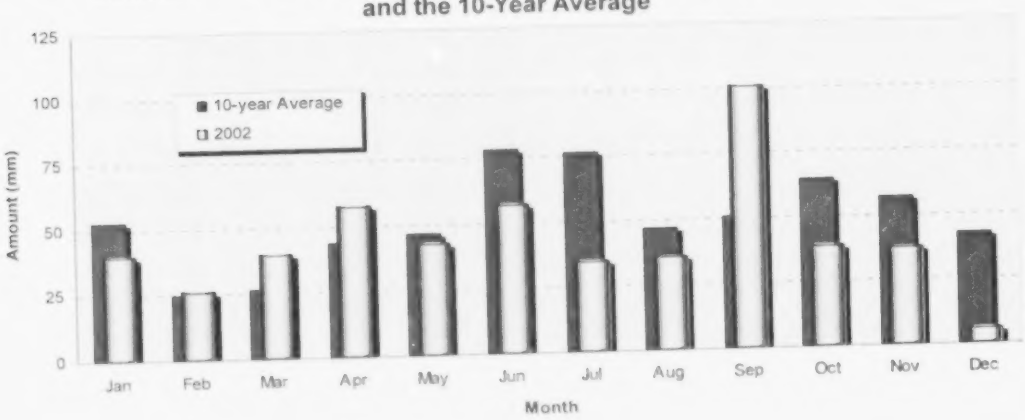
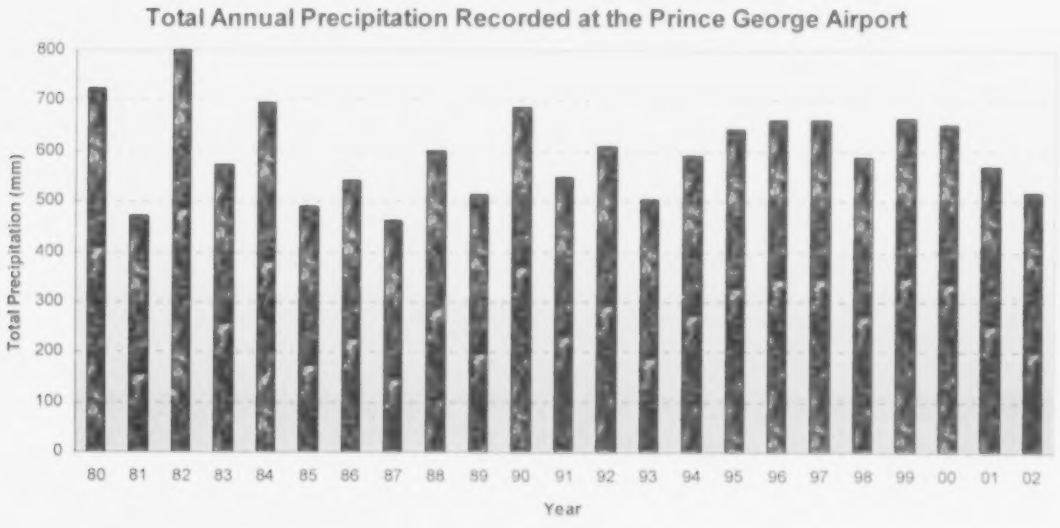


Figure 3.15 shows the trend in the total annual precipitation recorded at the Prince George Airport. The annual average precipitation in 2002 was the lowest recorded since 1993. In addition to precipitation, air quality is also affected by wind speed and direction, and emission trends.

Figure 3.15



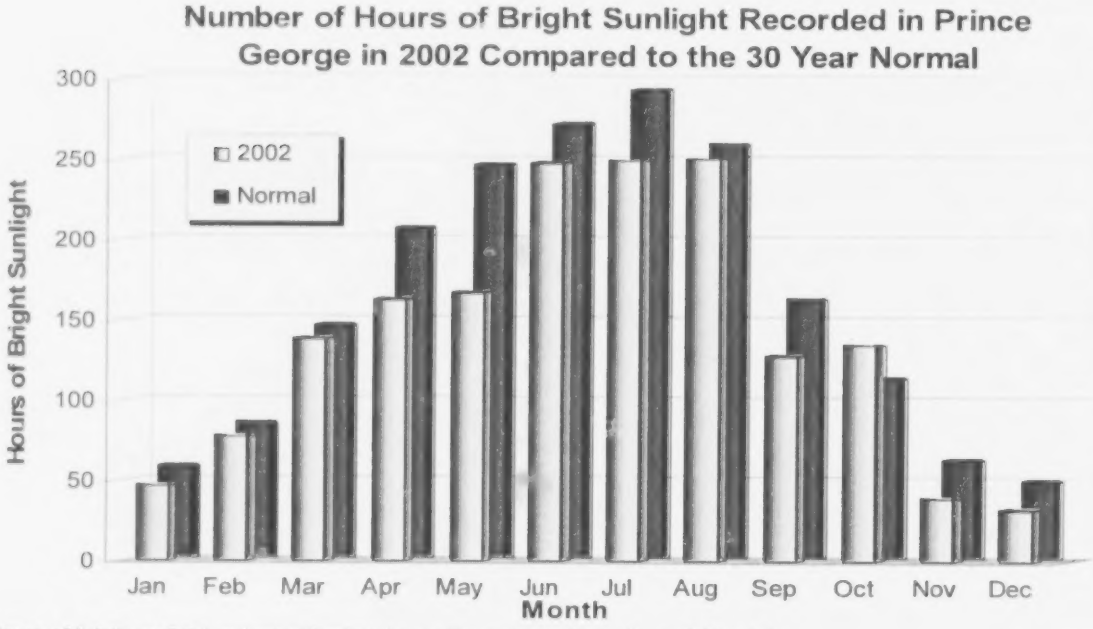
3.3 Analysis of Solar Radiation

Solar radiation can be beneficial or detrimental to air quality. High levels of pollution can build up in the airshed due to ground level temperature inversions. An inversion exists when the temperature aloft is warmer than that nearer the surface. Any emissions near the surface will stay closer to the surface during inversions. Strong solar radiation can break down inversions, resulting in better mixing. Clean air from the troposphere then replaces the polluted air near the ground and flushes polluted air out of the airshed.

On the other hand, during the breakdown of the inversion an event known as fumigation can occur. Fumigation occurs whenever a plume emitted from tall stacks is trapped above the surface in the inversion. As the morning inversion breaks down due to daytime heating this plume aloft is brought down to the surface for a short duration. Fumigations have been responsible for initiating and sustaining fine particulate episodes in the valley (WLAP, 2002). Pollutants such as SO_2, PM_{10} and $PM_{2.5}$, that have accumulated under inversions are occasionally drawn down into the valley during inversion breakdowns.

Also, solar radiation can contribute to the production of photochemical pollutants, helping transform primary pollutants into secondary pollutants, that may be more harmful. Ozone is the best known photochemical pollutant. Sulphates and nitrates can also develop due to solar radiation, adding to the amount of fine particles in the airshed. SO_2 can react with a cloud droplet and rapidly be converted to sulphate. Solar radiation can evaporate this cloud droplet, leaving behind a sulphate particle. Both ozone and fine particles are known to cause respiratory problems and will be discussed later in this report.

Figure 3.16



Hours of bright sunlight estimated for October to December using solar radiation data.

Figure 3.16 shows the 2002 seasonal trend in bright sunshine with high levels during the summer and low levels during the winter, as expected due to varying hours of daylight. Even though the longest period of daylight occurs around June 21, there were as many or more hours of bright sunshine recorded in July and August. When compared to the 30-year normal (1960-1990), the total hours of bright sunshine were well below normal during the summertime in 2002, which was similar in pattern to 2000 and 2001. Only the month of October had more hours of bright sunlight than normal. In fact, the total hours of bright sunlight recorded for ten out of the past thirteen years have been less than normal, with 1999, 2000, 2001 and 2002 having the least number of hours of bright sunlight (Table 3.2). The total hours of bright sunshine were the lowest ever recorded in Prince George in the past 13 years.

Table 3.2 Monthly Distribution of Hours of Bright Sunlight

	Normal	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Jan	56	47	73	22	79	28	8	84	42	68	37	54	79	46
Feb	84	77	79	51	126	46	94	128	92	106	91	94	105	77
Mar	146	153	154	186	182	162	142	170	121	148	163	115	153	138
Apr	206	224	256	178	167	209	185	143	243	216	194	184	200	163
May	245	170	302	238	259	249	335	205	277	337	173	243	178	167
Jun	271	228	226	297	191	233	257	224	232	263	211	235	232	248
Jul	292	336	295	333	254	290	228	323	258	327	285	240	232	250
Aug	259	255	258	298	252	333	222	214	315	246	246	210	239	251
Sep	162	242	178	68	248	135	237	161	209	184	166	144	194	128
Oct	112	77	137	97	105	105	70	87	88	71	159	89	112	135
Nov	61	39	44	48	65	63	47	57	23	40	55	52	30	39
Dec	48	31	36	43	29	35	43	40	26	46	33	55	48	32
Total	1943	1879	2037	1856	1957	1886	1866	1836	1927	2052	1814	1713	1799	1676

Bright sunlight hours are an important factor in determining air quality, as well as the intensity of this solar radiation. The intensity of solar radiation tends to be the highest in June and lowest in December, due to the tilt of the Earth's axis. In June the sun tends to be higher in the atmosphere, with higher per surface area energy and less reduction in solar intensity by absorption and scattering processes in the atmosphere. Figure 3.17 and 3.18 show the maximum daily solar radiation received at UNBC and Plaza, respectively in 2002. The fluctuation in daily levels is mainly due to the amount of cloud cover. Even during an overcast day some solar radiation reaches the Earth's surface. Note that the type of cloud cover and the reflection off snow may result in solar radiation being more intense than expected. A sky partly covered with cumulus clouds may cause solar radiation to be reflected off the clouds. An area on the ground may then get radiation from this reflection as well as radiation directly from the sun. There were several days in which the maximum amount of solar radiation at Plaza were higher than those at UNBC and vice versa. This is mainly due to cloudy conditions in the afternoon. The sun will break through these clouds in the afternoon for a short period reaching one monitor while the other monitors remains under the influence of the clouds.

Figure 3.17

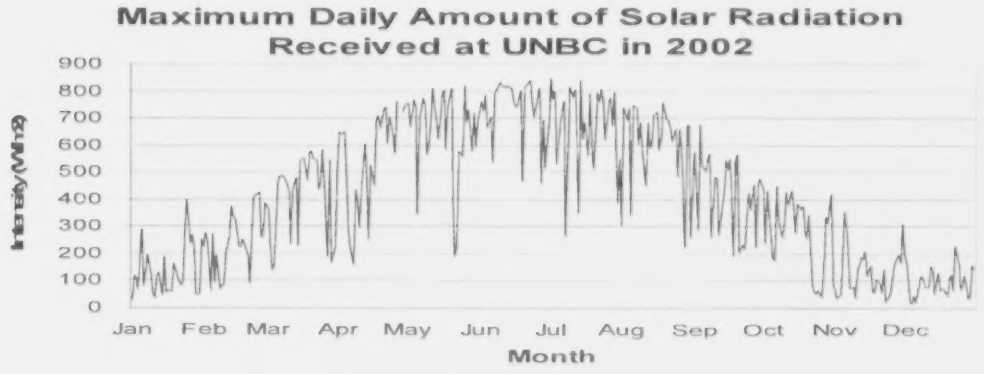
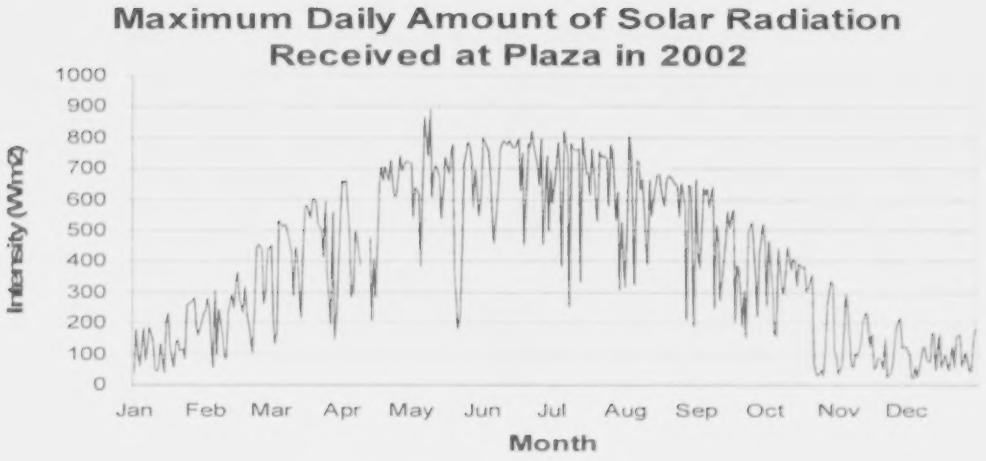


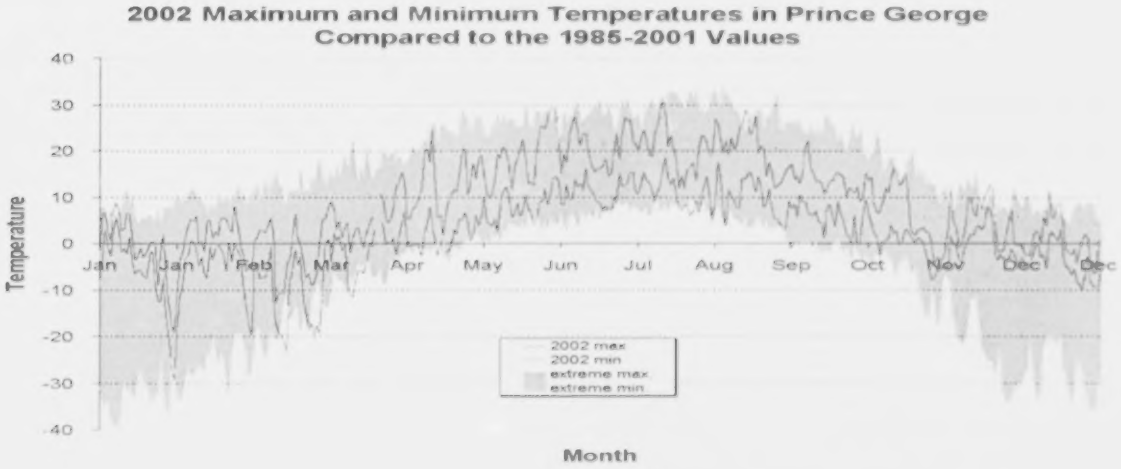
Figure 3.18

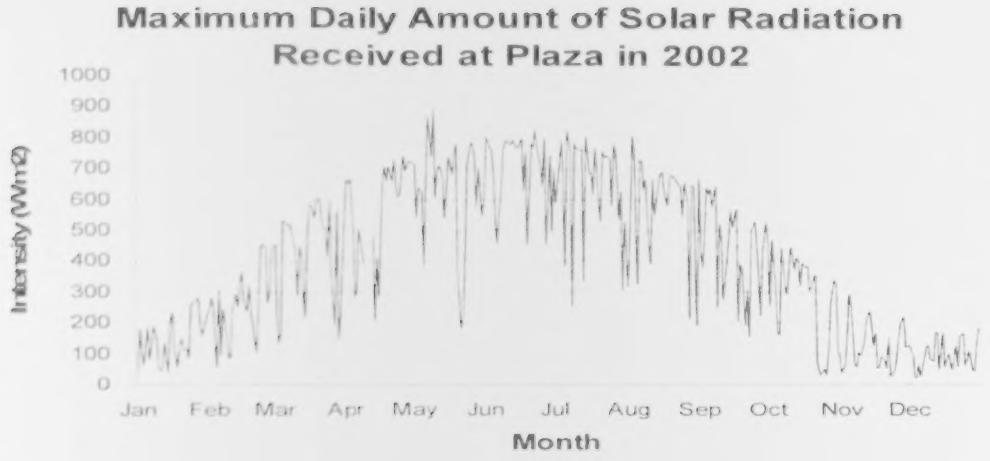


3.4 Analysis of Temperature

Temperature can have an influence on air pollution levels directly and indirectly. Indirectly, cold temperatures in Prince George can cause more emissions in the airshed from industrial and residential use of wood and other fuels. Also, vehicle emissions are known to increase in colder climates as a result of engines becoming less efficient and requiring more fuel to warm up the engines. A direct effect is that chemical reactions are known to be dependant on temperature. Most reactions have a direct relationship to temperature. Pollutants like ozone can be produced fast at warmer temperatures, while the destruction of ozone happens faster at warmer temperatures as well. It is uncertain as to whether the net ozone increases or decreases with temperatures, but it is thought by some that there is a net increase.

Figure 3.19





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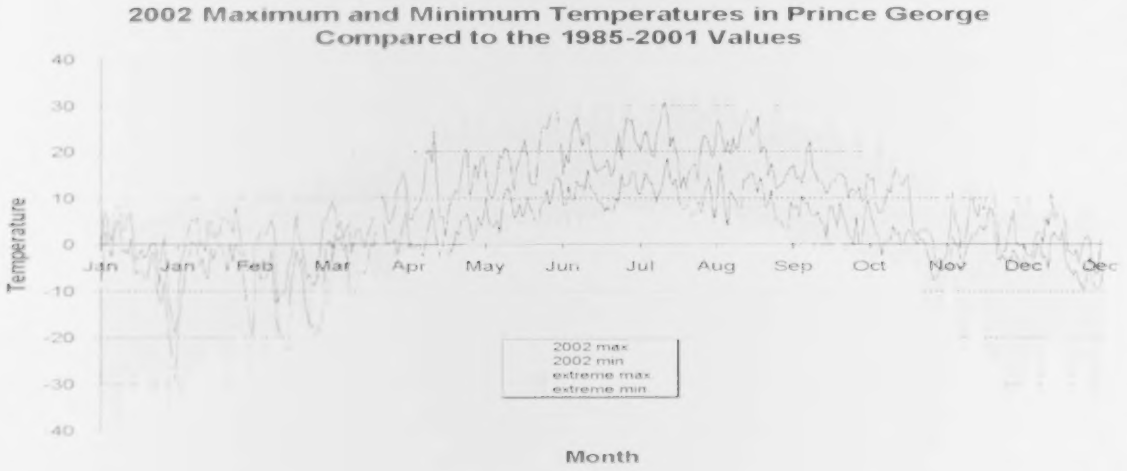


Fig 3.19 compares the daily maximum and minimum temperatures at the downtown site with the highest maximum and minimum temperatures recorded since 1985. There were five occasions in 2002 in which maximum temperatures were the highest ever recorded on those days in the past 16 years. During nine occasions the minimum temperature was the lowest ever recorded for that period in the past 16 years. The coldest period seem to occur in late winter (Feb. to March) and the period in which the temperatures were well above normal occurred in early winter (Nov. to Dec.).

Table 3.3 compares the monthly average temperatures recorded at the six meteorological stations in Prince George in 2002. Temperatures at the downtown location appear to be somewhat higher than all other sites for every month in 2002. This could be due to the heat island effect in which temperatures in urban areas are typically higher than rural areas. The lowest temperatures are recorded at sites located at higher elevation. Temperatures at higher elevations are normally lower than those at lower elevations because temperatures normally decrease as one ascends in altitude. However, temperatures at night are normally lower at low elevations than those at higher elevations because at night cold air sinks causing areas in valleys to be colder than hill tops. In Prince George, this may not be noticeable since there are other factors that may affect the temperatures. Four sites are located on top of buildings. Three of those sites (Plaza, UNBC, PG Pulp) have activity happening in the building continuously. Heat being released from these buildings may cause the temperatures to be higher. The Northwood site is located in an area that may be effluence by the lagoons from the pulp mill. Heat released from these lagoons during the winter may affect this monitor.

Table 3.3 Monthly Average Temperatures Recorded at Sites in Prince George for 2002

	Plaza 400	Northwood	PG Pulp	Glenview	Airport	UNBC
Jan	-3.99	-4.87	-4.81	-5.43	-5.75	-4.87
Feb	-1.13	-1.89	-1.92	-2.67	-2.96	-2.18
Mar	-4.87	-5.74	-5.74	-6.38	-6.68	-5.87
Apr	3.57	3.20	3.25	2.12	2.55	2.58
May	9.10	8.57	8.66	7.33	8.11	7.92
Jun	15.91	14.96	15.48	14.47	14.88	15.14
Jul	16.58	15.78	16.14	14.82	15.68	15.48
Aug	15.89	14.97	15.49	14.26	14.78	15.18
Sep	10.11	9.50	9.76	8.48	9.03	9.11
Oct	4.44	3.79	3.85	3.19	3.12	3.88
Nov	1.73	1.04	0.98	0.28	0.55	0.75
Dec	-1.75	-2.76	-2.68	-3.04	-2.98	-2.27

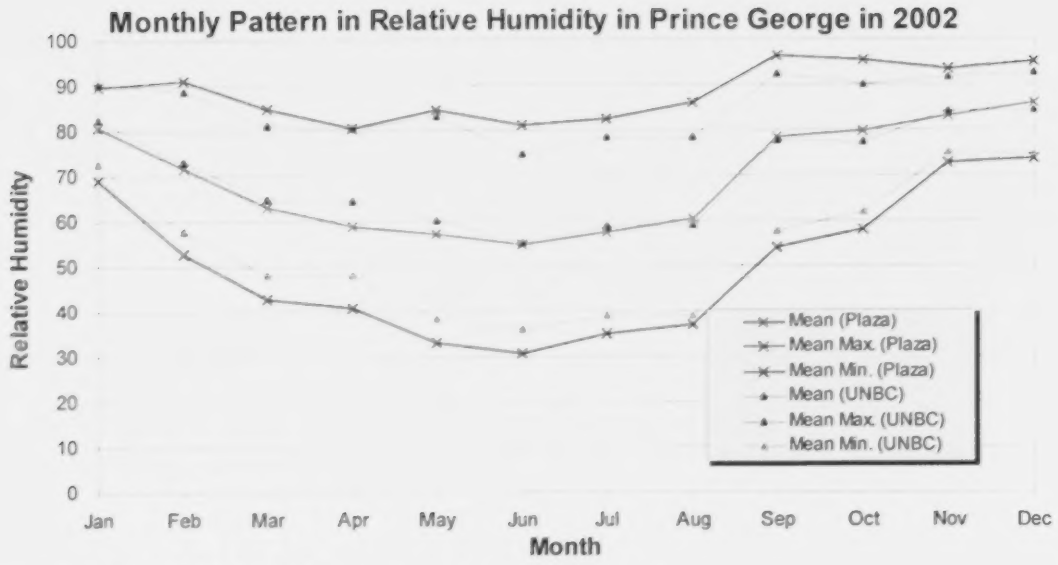
3.5 Analysis of Relative Humidity

Fig 3.20 shows that the mean monthly relative humidity at UNBC was similar to that at the Plaza site. Both sites show the relative humidity to be the lowest during summer and the highest during the winter. This indicates that the driest months are during summer and that during cold temperatures the airmass can't hold as much moisture as it can during warm temperatures. Therefore, even if a cold airmass has the same amount of moisture as a warm parcel of air the relative humidity will be higher. This is the main contributor to the higher relative humidity during the cold period of winter.

The average monthly maximum relative humidity was higher at Plaza than that at UNBC, but the average monthly minimum relative humidity was lower. The mean maximum relative humidity during the day usually occurs in the morning and reaches 100% when there is fog present. There is a higher frequency of fog which gets trapped in the bowl that there is at higher elevations. These periods of fog contribute to the maximum daily relative humidity being higher at Plaza than at UNBC for every month in 2002. There are occasions in which low clouds could affect the plateau but still stay above the bowl area. During those occasions one would expect to see 100% relativity humidity at UNBC but lower levels at Plaza.

The minimum daily relative humidity at Plaza was slightly lower than that at UNBC for most months in 2002. This could be due to UNBC being located at a higher elevation than the Plaza site. Temperatures decrease as elevation increases, hence daytime temperature will be cooler at UNBC than those in the bowl. Low relative normally occurs during good mixing so even if the air parcel at UNBC has the same amount of moisture compare to that at the lower elevation, the relative humidity will be slightly higher.

Figure 3.20



4. AMBIENT AIR QUALITY RESULTS AND TRENDS

4.1 Total Reduced Sulphur (TRS) Results

At low levels TRS is considered to be a nuisance pollutant, causing no adverse health effects, but producing odour problems. However, at levels > 1000 $\mu g/m^3$ (1 million μg = 1 gram) sensitive individuals may suffer headaches and nausea due to extreme odour. It should be noted that levels as high as this have never been recorded at the monitoring sites in Prince George.

As previously mentioned, TRS describes a group of sulphur compounds containing gases made up primarily of one or more of the following four compounds; dimethyl disulphide (DMDS), dimethyl sulphide (DMS), methyl mercaptan (MESH), and hydrogen sulphide (H_2S). Methyl mercaptan is the most odorous of the four main sulphur compounds that make up TRS and can be detected by a sensitive person in concentrations as low as 0.2 $\mu g/m^3$ (or about 0.1 parts per billion, ppb). The concentration is expressed in $\mu g/m^3$ of pollutant in air as H_2S equivalent.

The ultimate end product of any sulphur compound (TRS or SO_2) is that it is oxidized to form sulphate (a secondary pollutant) which may become sulphuric acid, a component of acid rain. Unlike TRS or SO_2, sulphates are in the form of very small particles, about 0.1 micrometre in size. The rate at which sulphates are formed is highly variable and can take anywhere from 2 to 48 hours. It is this end product that has the detrimental effects on health and vegetation in the long term. Human health effects are lung and breathing problems which are amplified during times when weather systems produce humid conditions. High humidity causes more sulphate to be formed and to be retained in the lung tissue.

The current analyzers have a detection limit of about 1.5 $\mu g/m^3$ or 1 ppb (Fig 4.1.1). The analyzer measures the total amount of TRS gases by oxidizing these gases in an oven (900° C) to form SO_2. The SO_2 concentration is then measured using fluorescent excitation by ultra-violet radiation.

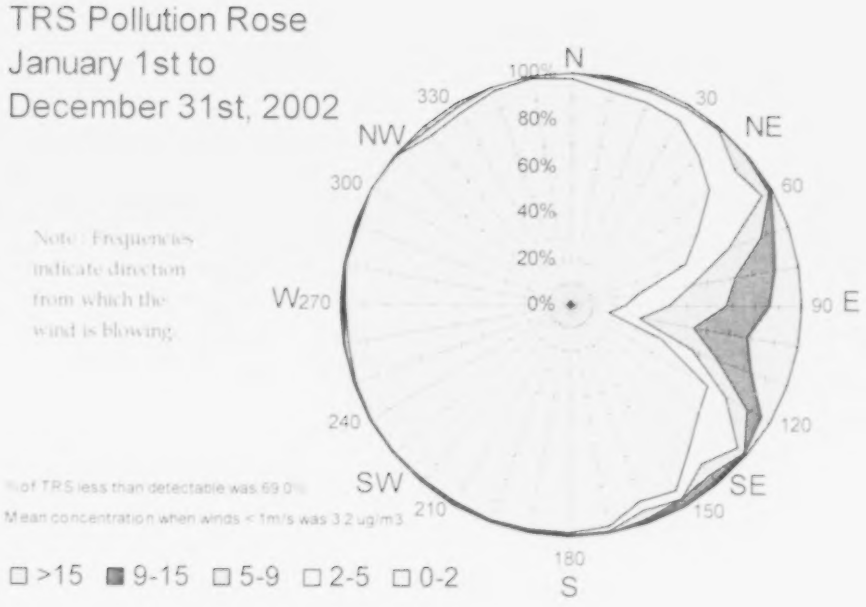
Fig. 4.1.1 TRS Monitor Located at Plaza

In 1999, the number of TRS monitoring sites was decreased to three with the removal of the TRS monitor at Hart Highlands - Glenview in July after one year of monitoring. Data for this site as well as other decommissioned TRS monitoring sites are in Appendix E.

The quality of the TRS data was evaluated through monthly calibrations and independent auditing in May and October. The auditing results in Appendix D, Table D-1 indicate that all the TRS monitors performed satisfactorily in 2002, within the allowable instrument deviation of +/-15%. The annual percent of valid data (ranging from 93.2% at Plaza to 95.6% at Jail) was acceptable.

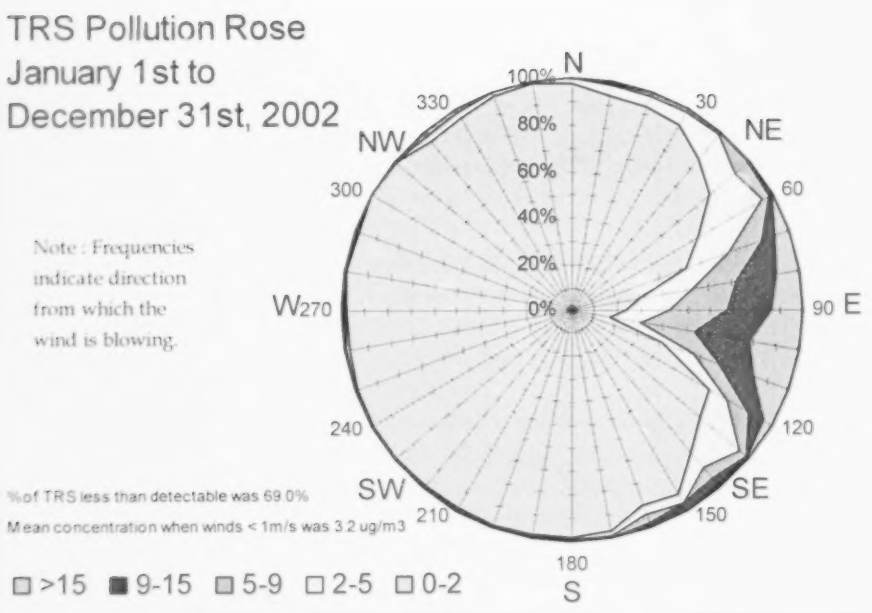
Figure 4.1.2 shows the TRS pollution rose for the Plaza site based on the 2002 meteorological data at that site. Wind directions were only considered whenever wind speeds were $\geq$ 1 m/s (winds below 1 m/s are less able to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). The highest concentrations occurred with winds from the east even though the sources are located northeast of this monitoring site. This is expected since the winds blowing from the northeast are deflected eastward by the hills located south of the pulp mills and refinery before reaching the monitoring site (Section 3.2). Detectable TRS levels were recorded at almost all the 16 wind sectors. This is not an indication of sources in all these sectors, but a result of TRS levels building up in the area under calm conditions, and once wind speeds increase (regardless of direction) it takes time to flush these pollutants out of the airshed.

Figure 4.1.2: TRS Pollution Rose Recorded at Plaza for 2002



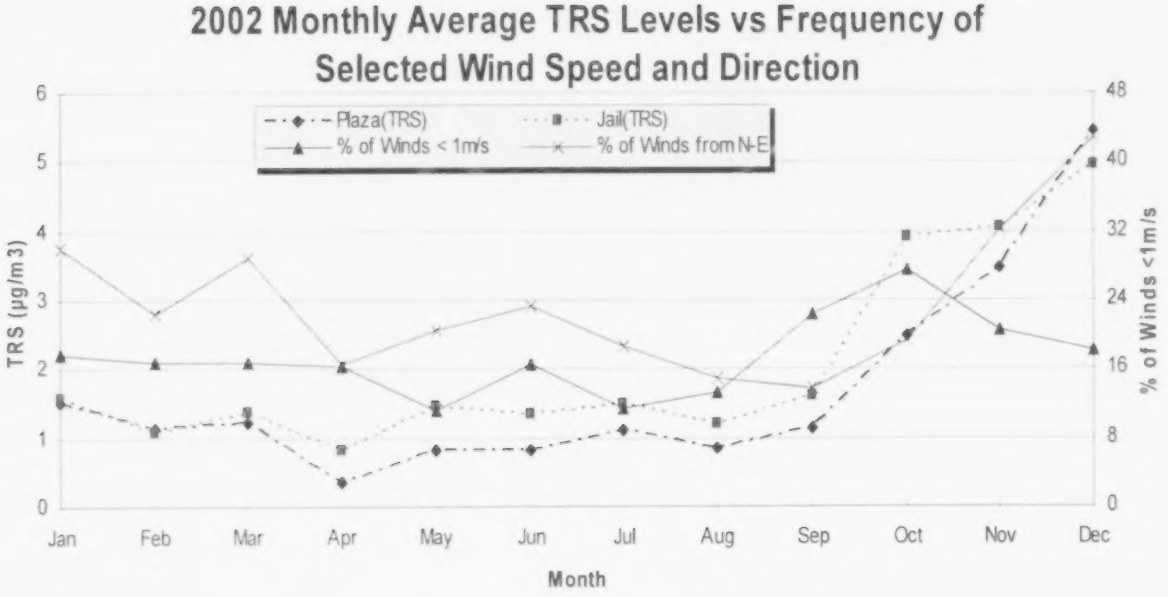
Ambient TRS levels are affected by wind speed as well as direction. The average concentration at Plaza in 2002 during calm winds (< 1 m/s) was 3.2 $\mu g/m^3$ compared to 1.4 $\mu g/m^3$ when winds were not calm. The relationship between percent frequency of calm winds (at Plaza) and TRS levels is illustrated in Figure 4.1.3. Higher frequency of calm winds normally correlates well with higher monthly TRS levels. In 2002, the seven highest monthly average TRS levels at Plaza occurred during the seven months which had the highest frequency of calm winds.

Figure 4.1.3



Ambient TRS levels are affected by wind speed as well as direction. The average concentration at Plaza in 2002 during calm winds (< 1 m/s) was 3.2 $\mu g/m^3$ compared to 1.4 $\mu g/m^3$ when winds were not calm. The relationship between percent frequency of calm winds (at Plaza) and TRS levels is illustrated in Figure 4.1.3. Higher frequency of calm winds normally correlates well with higher monthly TRS levels. In 2002, the seven highest monthly average TRS levels at Plaza occurred during the seven months which had the highest frequency of calm winds.

Figure 4.1.3



Wind direction also plays an important role in the TRS Levels. Four of the five months that recorded the highest TRS levels at Plaza occurred during the four months with the highest percent of northeast winds. These months were winter months when temperature inversions tend to be the strongest. A combination of wind speed, wind direction and temperature inversions all contribute to higher TRS levels.

Tables 4.1.1 to 4.1.3 show average monthly and annual TRS concentrations for each of the three Prince George ambient air monitoring stations and their respective levels of exceedance of the hourly and daily level A and level B air quality objectives. Monthly averages ranged from a high of 5.4 $\mu g/m^3$ at Plaza (in December) to 0.1 $\mu g/m^3$ at Lakewood (during April, May and July). Jail had the highest annual average, followed by the Plaza. The Jail also recorded the highest frequency of exceedances of the Level A and B 1-hour and daily objectives.

Plaza recorded 25 hours above the one-hour Level B objective, and all of those exceedances occurred in October - December. The Plaza site also recorded the highest one-hour concentration (57 $\mu g/m^3$). Lakewood recorded no exceedances of the Level B one-hour objective.

Table 4.1.1
2002 Monthly Summary of TRS Data at Plaza

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	$>7\mu g/m^3$	$>28\mu g/m^3$	($\mu g/m^3$)	$>3\mu g/m^3$	$>6\mu g/m^3$	($\mu g/m^3$)
January	1.5	62	0	17	6	1	6.7
February	1.1	43	0	14	4	1	7.1
March	1.2	40	0	24	3	2	7.6
April	0.4	0	0	6	0	0	2.0
May	0.8	29	0	21	1	0	5.2
June	0.8	23	0	18	1	0	5.7
July	1.1	38	0	24	3	2	9.1
August	0.8	27	0	26	4	0	8.1
September	1.1	37	0	20	3	0	5.8
October	2.5	79	10	47	8	5	13.1
November	3.5	149	3	41	10	6	15.7
December	5.4	199	12	57	18	8	18.4
Annual	**1.7**	**726**	**25**	**57**	**61**	**25**	**18.4**

Table 4.1.2
2002 Monthly Summary of TRS Data at Jail

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	$>7\mu g/m^3$	$>28\mu g/m^3$	($\mu g/m^3$)	$>3\mu g/m^3$	$>6\mu g/m^3$	($\mu g/m^3$)
January	1.6	50	0	18	5	1	7.6
February	1.1	32	0	18	3	0	5.7
March	1.4	34	0	17	3	0	4.4
April	0.8	11	1	43	0	0	5.2
May	1.5	57	2	30	7	0	7.6
June	1.3	54	0	27	4	1	9.7
July	1.5	57	1	30	5	2	8.0
August	1.2	48	0	24	5	1	8.5
September	1.6	66	0	24	9	1	9.4
October	3.9	125	21	44	11	7	19.2
November	4.1	165	2	34	13	8	16.3
December	4.9	195	8	41	20	10	16.2
Annual	**2.1**	**894**	**35**	**44**	**85**	**31**	**19.2**

Table 4.1.3
2002 Monthly Summary of TRS Data at Lakewood

	Monthly Average ($\mu g/m^3$)	No. of 1-Hour Values		Maximum Hourly Average ($\mu g/m^3$)	No. of Daily Values		Maximum 24 Hour Average ($\mu g/m^3$)
		>7$\mu g/m^3$	>28$\mu g/m^3$		>3$\mu g/m^3$	>6$\mu g/m^3$	
January	1.2	11	0	13	2	0	4.8
February	0.5	5	0	10	0	0	3.3
March	0.4	10	0	17	1	0	3.7
April	0.1	0	0	3	0	0	0.7
May	0.1	0	0	6	0	0	0.6
June	0.2	0	0	4	0	0	1.4
July	0.1	0	0	3	0	0	0.9
August	0.3	0	0	6	0	0	2.0
September	0.3	1	0	7	0	0	1.7
October	0.6	13	0	14	1	1	6.0
November	1.0	18	0	16	2	0	4.4
December	2.7	133	0	23	12	5	11.8
Annual	**0.6**	**191**	**0**	**23**	**18**	**6**	**11.8**

Figure 4.1.4

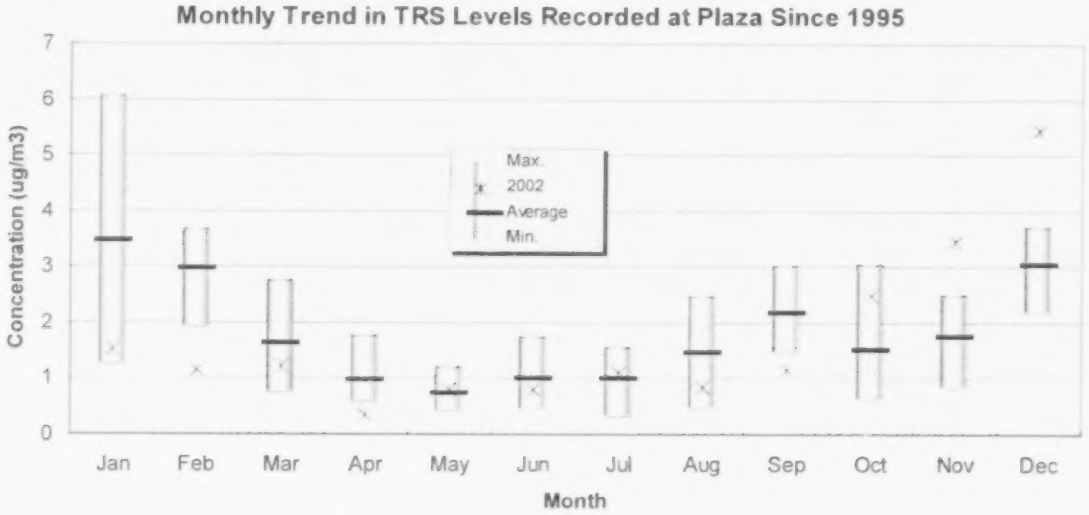


Figure 4.1.4 shows the range in monthly averages recorded at Plaza since 1995. Data collected prior to 1995 was not used because the method used to archive that data could result in slightly lower monthly averages than expected. Monthly averages ranged from a high of 6.1 $\mu g/m^3$ (Jan. 1995) to a low of 0.3 $\mu g/m^3$ (July 2001). Monthly averages at Plaza tend to be the highest during the winter and the lowest during the early summer. Monthly average levels have not exceeded 1.8 ug/m3 in the months from April to July since 1995. Monthly averages in 2002 were above normal for three months (October, November and

December). Levels during November and December were the highest average levels ever recorded for those months and the December average was the second highest ever recorded at that site (since 1995). 2002 levels during the months of February, April and September were the lowest recorded for those months (since 1995).

Figure 4.1.5 shows the range in monthly averages recorded at Lakewood since 1995. Monthly averages ranged from a high of 4.1 $\mu g/m^3$ (Jan. 1995) to a low of 0.05 $\mu g/m^3$ (April 2001). Similar to Plaza, monthly averages at Lakewood tend to be the highest during the winter and the lowest during the summer. Average levels never exceeded 0.5 ug/m3 in the months from April to July since 1995. Monthly average in 2002 was above normal only for November and December. The monthly averages in February and May were the lowest monthly average ever recorded for those months (since 1995).

Figure 4.1.5

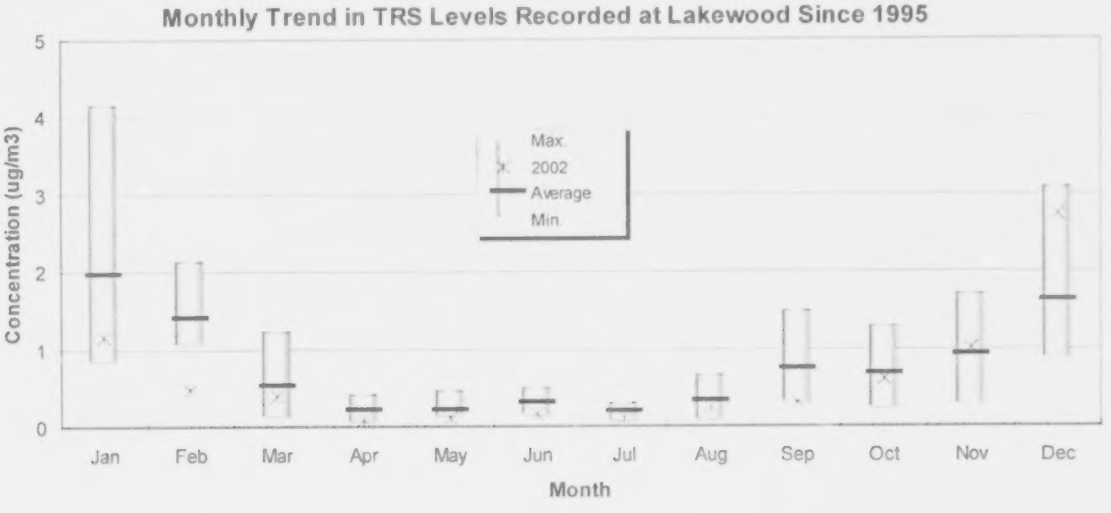
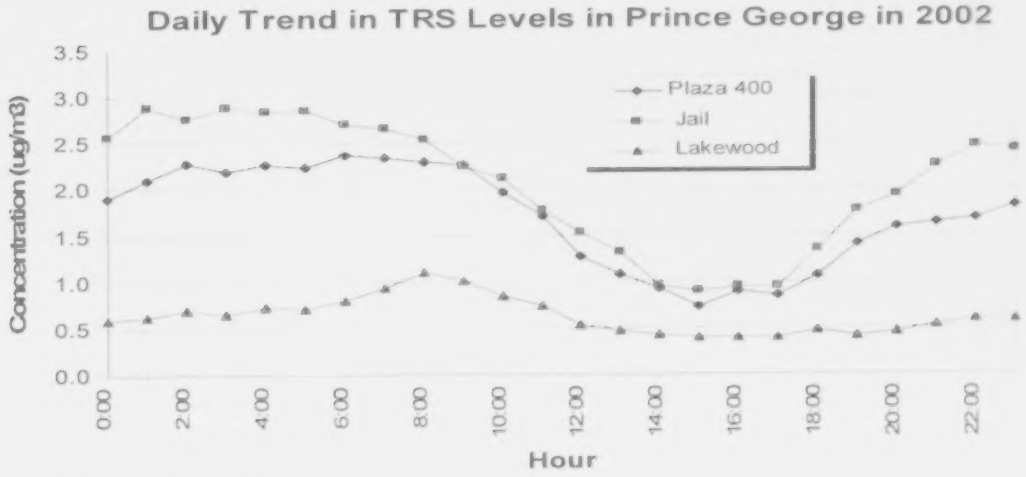


Figure 4.1.6 shows the range in monthly averages recorded at Jail since 1995. Monthly averages ranged from a high of 6.2 $\mu g/m^3$ (Sept.1995) to a low of 0.7 $\mu g/m^3$ (June 2001). Unlike the other two sites, monthly averages at Jail tend to be the highest during the late winter and again during the early autumn, and the lowest during the late spring. Average levels tend to gradually increase from April to August. Monthly averages in 2002 were above normal for three consecutive months (October to December), with levels recorded in December being the highest recorded in that month (since 1995). 2002 levels during the month of February, March, April and September were the lowest monthly average levels recorded (since 1995) for those months.

Figure 4.1.6

Figure 4.1.7 shows the average TRS concentration for each hour of the day in 2002 for sites in Prince George. This gives a general pattern of TRS levels that can be expected on average throughout the day at each site. Levels at both Plaza and Jail start increasing in the evening, which is an indication of a nocturnal ground level inversion developing. Emissions get trapped in this inversion and gradually build up overnight. When the inversion breaks in the morning, TRS levels start decreasing. TRS levels are the lowest in the afternoon when mixing is at its greatest. At the Lakewood site, levels do not start increasing until after midnight, but the increase is slight compared to the other two sites. This is likely due to this site being furthest from the sources and the amount of time for accumulated TRS levels to reach this site, or distance from the Fraser River which may channel cold air flows from the sources upriver.

Figure 4.1.7



4.1.1 TRS Annual Trends

The data from the Plaza station, the Jail, Lakewood stations were examined to reveal trends in Prince George. Archived TRS data for Van Bien (1982-1995), Foreman Flats (1982-1995), and Glenview (1998-1999) are provided in Appendix E. The following tables (Table 4.1.4 - Table 4.1.6) and Figure 4.1.8 summarize the TRS data from the five stations over the full monitoring period.

The annual average concentrations at all three currently monitored sites are some of the lowest recorded since monitoring began. The levels recorded at Plaza and Jail are about 20% of what was recorded before 1989 (Fig. 4.1.8). The reduction of odorous emissions from the pulp mill effluent treatment ponds in 1990 produced a significant improvement in air quality at all stations. Since these source reductions, TRS levels at the Plaza and Jail sites have gradually decreased. The Jail also recorded one of the lowest number of exceedances of the Level A hourly and daily objectives. The Level B Objective is still being exceeded at Plaza, indicating the need for the additional TRS reductions called for in the Prince George Air Quality Plan (see Prince George Airshed Technical Management Committee, 1998). The rare occurrence of Level B hourly exceedances at Lakewood in 1999 indicates that the annual average at Plaza (1.7 $\mu g/m^3$) will likely have to be similar to the Lakewood average (< 1.0 $\mu g/m^3$) to accomplish the objective of eliminating these exceedances.

Table 4.1.4
Annual Trend Summary of TRS Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. (%) of 1-Hour Values >7$\mu g/m^3$	No. (%) of 1-Hour Values >28$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Daily Values >3$\mu g/m^3$	No. (%) of Daily Values >6$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of hours Instrument Operated
1980	5.9	1085 (16.0%)	449 (6.6%)	163	127 (45.0%)	85 (30.1%)	62.4	6772
1981	6.0	1276 (16.9%)	566 (7.5%)	241	136 (43.2%)	101 (32.1%)	53.8	7558
1982	5.3	1241 (15.1%)	445 (5.4%)	198	156 (45.5%)	111 (32.4%)	41.3	8235
1983	8.6	1670 (20.7%)	817 (10.1%)	177	180 (53.4%)	150 (44.5%)	90.5	8082
1984	4.7	978 (11.9%)	372 (4.5%)	227	121 (35.2%)	84 (24.4%)	51.7	8246
1985	4.8	875 (12.3%)	406 (5.7%)	297	106 (35.8%)	78 (26.4%)	81.6	7115
1986	7.9	1295 (20.1%)	677 (10.5%)	289	126 (46.8%)	102 (37.9%)	61.4	6456
1987	9.0	1806 (21.8%)	972 (11.7%)	218	174 (48.2%)	143 (39.6%)	69.0	8280
1988	7.3	1633 (19.7%)	792 (9.5%)	194	159 (44.0%)	121 (33.5%)	69.4	8297
1989	5.9	1376 (16.9%)	594 (7.3%)	184	140 (40.8%)	111 (32.4%)	41.8	8166
1990	2.7	905 (11.0%)	187 (2.3%)	122	100 (28.0%)	57 (16.0%)	47.0	8234
1991	2.2	925 (11.2%)	43 (0.5%)	58	84 (23.3%)	46 (12.8%)	19.4	8256
1992	2.1	882 (10.6%)	34 (0.4%)	69	89 (24.5%)	49 (13.5%)	18.4	8300
1993	2.4	956 (11.4%)	92 (1.1%)	72	89 (24.6%)	54 (14.9%)	29.8	8360
1994	1.9	790 (9.5%)	22 (0.3%)	67	84 (23.3%)	34 (9.4%)	19.1	8295
1995	1.9	757 (9.2%)	20 (0.2%)	44	93 (26.1%)	32 (9.0%)	20.5	8205
1996	1.7	622 (7.5%)	28 (0.3%)	103	71 (19.8%)	25 (7.0%)	27.2	8262
1997	1.6	654 (7.8%)	13 (0.2%)	40	65 (17.9%)	22 (6.0%)	12.9	8371
1998	2.2	958 (11.6%)	9 (0.1%)	50	88 (24.6%)	32 (8.9%)	19.5	8245
1999	1.7	784 (9.5%)	13 (0.2%)	44	71 (19.8%)	24 (6.7%)	18.5	8247
2000	1.5	675 (8.1%)	16 (0.2%)	45	58 (15.9%)	23 (5.5%)	21.8	8314
2001	1.7	882 (10.7%)	5 (0.1%)	35	68 (18.7%)	25 (6.9%)	21.0	8257
2002	1.7	726 (8.9%)	25 (0.3%)	57	61 (17.3%)	25 (7.1%)	16.4	8167

Table 4.1.5
Annual Trend Summary of TRS Data at Jail

Year	Annual Average ($\mu g/m^3$)	No. (%) of 1-Hour Values >7$\mu g/m^3$	No. (%) of 1-Hour Values >28$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Daily Values >3$\mu g/m^3$	No. (%) of Daily Values >6$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
1981	7.2	1673 (21.7%)	638 (8.3%)	177	151 (47.0%)	121 (37.7%)	59.6	7701
1982	8.8	1169 (23.8%)	519 (10.6%)	149	125 (61.0%)	99 (48.3%)	53.5	4915
1983	11.0	2051 (27.3%)	1066 (14.2%)	156	184 (58.8%)	151 (48.2%)	70.2	7511
1984	6.5	1341 (17.6%)	593 (7.8%)	170	136 (42.8%)	109 (34.3%)	54.8	7638
1985	6.4	1483 (19.1%)	546 (7.0%)	149	145 (44.8%)	117 (36.1%)	44.9	7773
1986	9.8	2404 (29.1%)	1028 (12.4%)	347	197 (57.1%)	169 (49.0%)	68.0	8268
1987	11.6	2268 (29.0%)	1306 (16.7%)	382	200 (59.0%)	175 (51.6%)	86.0	7817
1988	11.6	2307 (27.9%)	1343 (16.2%)	312	197 (54.6%)	166 (46.0%)	94.6	8267
1989	9.2	1852 (25.8%)	793 (11.0%)	212	174 (54.5%)	134 (42.0%)	68.3	7183
1990	5.4	927 (14.3%)	215 (3.3%)	177	91 (32.6%)	66 (23.7%)	46.7	6494
1991	3.1	1195 (14.4%)	138 (1.7%)	126	117 (32.3%)	61 (16.9%)	39.2	8316
1992	3.7	1103 (14.9%)	71 (1.0%)	78	109 (34.0%)	66 (20.6%)	17.7	7387
1993	3.8	1343 (16.7%)	201 (2.5%)	69	123 (35.4%)	86 (24.8%)	37.7	8061
1994	3.1	1214 (15.1%)	108 (1.3%)	57	119 (35.0%)	67 (19.7%)	19.7	8017
1995	3.3	1274 (15.2%)	73 (0.9%)	64	157 (43.1%)	64 (17.6%)	23.0	8359
1996	2.6	1043 (12.5%)	42 (0.5%)	62	112 (30.8%)	53 (14.6%)	18.8	8359
1997	2.5	1157 (13.9%)	42 (0.5%)	55	119 (32.7%)	37 (10.2%)	21.3	8347
1998	3.1	1488 (17.9%)	57 (0.7%)	51	138 (38.2%)	62 (17.2%)	26.1	8314
1999	2.4	1085 (13.4%)	44 (0.5%)	123	107 (30.2%)	43 (12.1%)	26.5	8117
2000	2.4	1079 (13.1%)	37 (0.5%)	62	105 (28.8%)	43 (11.8%)	18.4	8214
2001	2.2	1106 (13.2%)	13 (0.2%)	37	93 (25.7%)	42 (11.6%)	20.2	8352
2002	2.1	894 (10.7%)	35 (0.4%)	44	85 (23.2%)	31 (8.5%)	18.5	8375

Table 4.1.6

Annual Trend Summary of TRS Data at Lakewood

Year	Annual Average ($\mu g/m^3$)	No. (%) of 1-Hour Values >7$\mu g/m^3$	No. (%) of 1-Hour Values >28$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Daily Values >3$\mu g/m^3$	No. (%) of Daily Values >6$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of hours Instrument Operated
1982	-	176 (3.0%)	22 (0.4%)	85	22 (9.1%)	13 (5.4%)	19.7	5785
1983	2.6	615 (7.9%)	147 (1.9%)	99	79 (24.5%)	43 (13.4%)	40.7	7737
1984	0.9	199 (2.4%)	15 (0.2%)	64	34 (9.9%)	10 (2.9%)	15.4	8269
1985	1.0	216 (2.9%)	28 (0.4%)	50	29 (9.3%)	12 (3.9%)	21.6	7456
1986	1.7	439 (5.6%)	110 (1.4%)	71	51 (15.7%)	32 (9.9%)	27.1	7807
1987	1.6	461 (6.0%)	106 (1.4%)	92	51 (15.6%)	34 (10.4%)	35.7	7680
1988	1.1	270 (3.6%)	38 (0.5%)	64	38 (11.8%)	23 (7.1%)	17.5	7462
1989	0.7	170 (2.8%)	33 (0.5%)	92	22 (8.1%)	8 (2.9%)	28.0	6057
1990	-	66 (1.2%)	3 (0.05%)	79	8 (3.4%)	1 (0.4%)	10.5	5484
1991	0.6	173 (2.3%)	3 (0.04%)	37	19 (5.7%)	4 (1.2%)	18.7	7667
1992	0.6	214 (2.6%)	0 (0.00%)	27	22 (6.0%)	9 (2.5%)	11.7	8351
1993	0.9	308 (4.4%)	6 (0.09%)	86	32 (10.7%)	13 (4.4%)	19.4	6952
1994	0.6	147 (1.8%)	2 (0.02%)	74	21 (5.9%)	4 (1.1%)	11.5	8196
1995	0.9	270 (3.2%)	2 (0.02%)	37	37 (10.2%)	11 (3.0%)	15.0	8358
1996	0.7	227 (2.7%)	8 (0.1%)	44	27 (7.5%)	7 (1.9%)	15.0	8281
1997	0.7	174 (2.1%)	0 (0.0%)	27	17 (4.8%)	4 (1.1%)	9.8	8211
1998	0.7	215 (2.6%)	0 (0.0%)	18	21 (6.0%)	5 (1.4%)	10.7	8204
1999	0.6	172 (2.1%)	1 (0.01%)	28	14 (4.0%)	5 (1.4%)	9.5	8191
2000	0.5	157 (1.9%)	0 (0.0%)	23	15 (4.1%)	3 (0.8%)	12.8	8348
2001	0.7	249 (3.0%)	0 (0.0%)	23	21 (5.8%)	9 (2.5%)	13.0	8345
2002	0.6	191 (2.3%)	0 (0.0%)	23	18 (5.2%)	6 (1.7%)	10.5	8254

Even though the rate of Level A daily exceedances at Plaza was the second lowest in the past eight years, exceedances of the Level B one-hour objective were the highest recorded

at this site since 1996. The percent of exceedances of the one-hour Level A and daily Level A and B objectives recorded at Jail were the lowest recorded at this site.

Figure 4.1.8

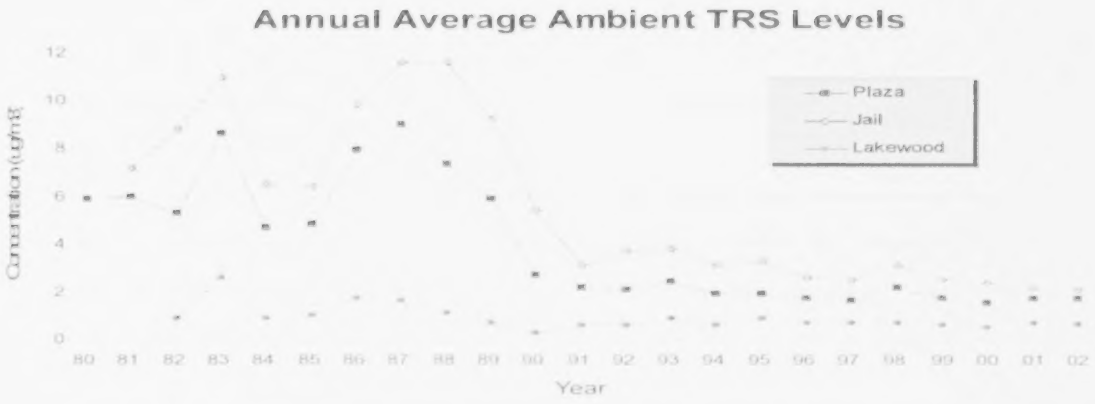


Figure 4.1.9 shows rolling annual average TRS levels recorded at the three monitoring sites in Prince George. The rolling annual average was used to reduce seasonal influences on the trends. A rolling annual average is the average for a 365 consecutive day period (i.e., the average on July 22, 1998 is for the period from July 23, 1997 to July 22, 1998). Presently, TRS concentrations at all three sites are about 55-70% of what they were in 1993 and only about 20-40% of what they were in 1987. Annual averages at the Lakewood site showed a slight decrease of about 0.2 $\mu g/m^3$ since Jan. 1993, and the Jail site averages decreased about 1.5 $\mu g/m^3$ since 1993.

Fig. 4.1.9

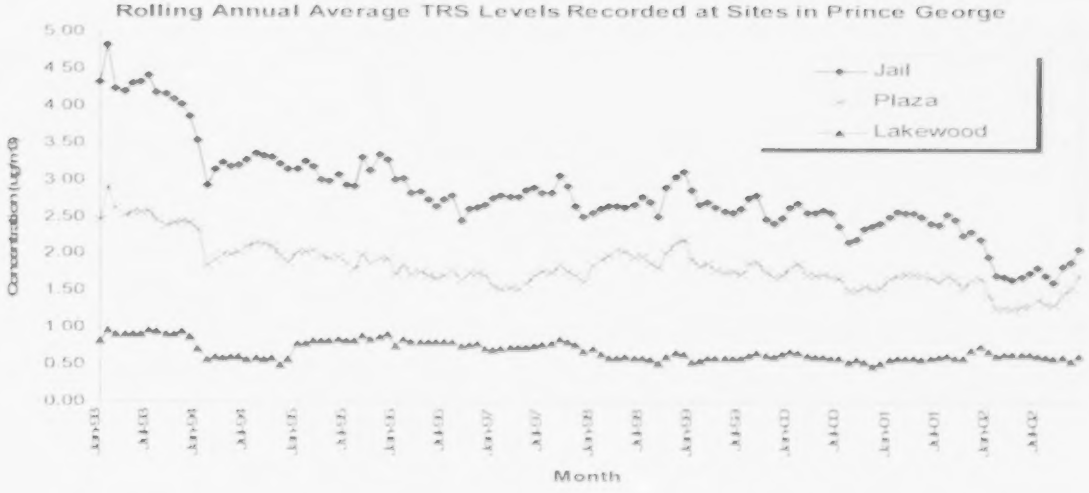
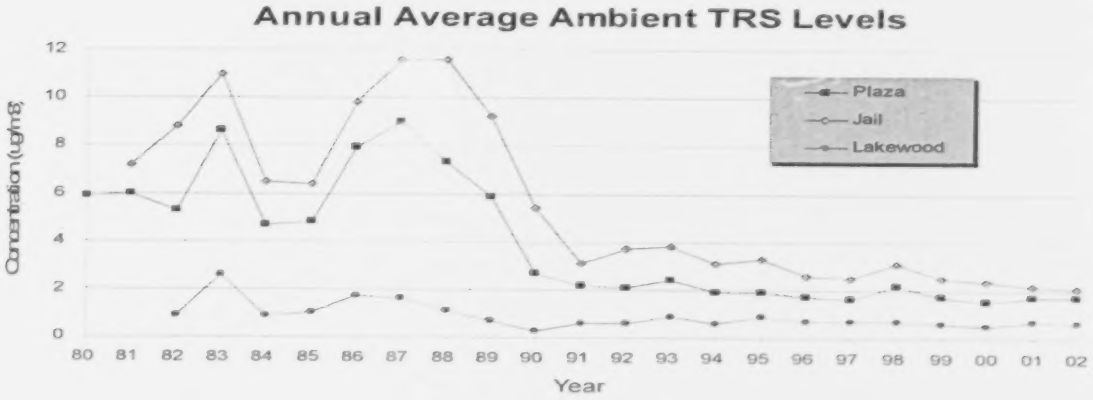


Table 4.1.7 shows the annual percentiles of TRS levels for the past seven years. All three sites showed a slight decrease in the higher percentiles for TRS from 1995 to 2002.

at this site since 1996. The percent of exceedances of the one-hour Level A and daily Level A and B objectives recorded at Jail were the lowest recorded at this site.

Figure 4.1.8



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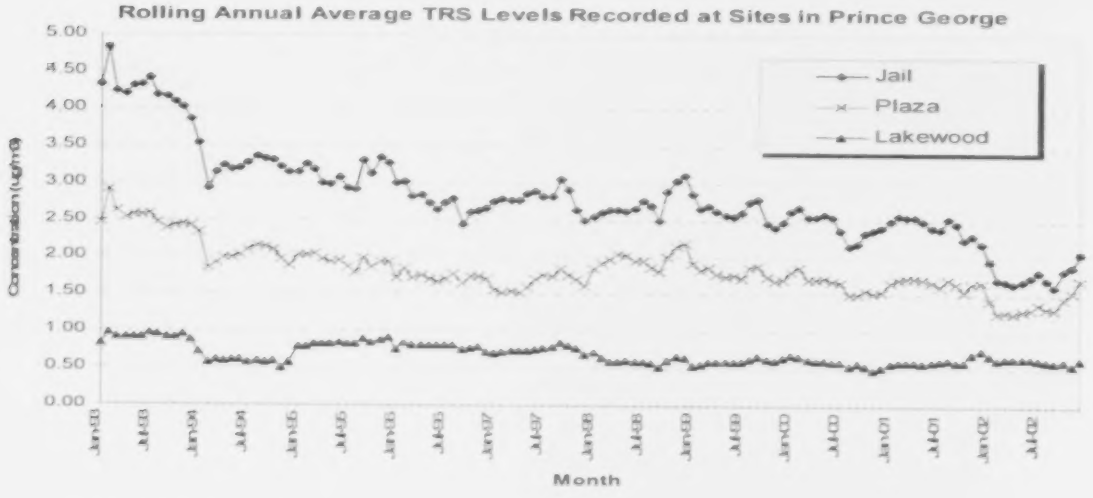


Table 4.1.7 shows the annual percentiles of TRS levels for the past seven years. All three sites showed a slight decrease in the higher percentiles for TRS from 1995 to 2002.

However, the higher percentiles at Plaza in 2002 were similar to those in 1996. The 95th percentile at Plaza in 2000 was 6 µg/m^3 compared to the 90th percentile of 6-7 µg/m^3 in the previous five years, as well as 2001 and 2002. That means in 2000 levels were over 6 µg/m^3 for only 5% of the time at Plaza but were over 6 µg/m^3 for about 10% of the time in every other year. The 2002 levels at both the Jail and Lakewood were similar to those in the previous three years.

Table 4.1.7
Percentiles of 1-hour TRS Levels Recorded at the Three TRS monitoring Sites

Pollutant	Year	Percentile (µg/m^3)									Max. (µg/m^3)	Average (µg/m^3)	No. of Samples
		50	60	70	75	80	90	95	98	99			
Plaza													
	1995	0	1	1	3	3	7	11	17	21	44	2.12	8205
	1996	0	0	1	1	3	6	10	16	20	103	1.78	8229
	1997	0	0	1	1	1	6	9	13	17	40	1.60	8372
	1998	0	1	1	1	3	7	11	16	18	50	2.19	8245
	1999	0	0	1	1	1	6	10	16	17	44	1.69	8247
	2000	0	0	0	0	1	1	6	9	14	45	1.53	8314
	2001	0	0	1	1	3	7	10	13	16	35	1.67	8257
	2002	0	0	1	1	1	6	10	17	20	57	1.70	8167
Jail													
	1995	0	1	3	4	6	11	17	24	28	64	3.39	8359
	1996	0	1	3	3	4	10	14	20	24	62	2.81	8359
	1997	0	1	1	3	4	9	13	18	23	55	2.47	8347
	1998	0	1	3	4	6	11	16	21	26	51	3.09	8314
	1999	0	1	1	1	4	9	13	18	24	123	2.44	8117
	2000	0	1	1	3	4	9	11	17	23	62	2.39	8214
	2001	0	0	1	1	3	9	13	17	20	37	2.17	8352
	2002	0	0	1	1	3	7	11	18	23	44	2.07	8375
Lakewood													
	1995	0	1	1	1	1	4	6	10	13	37	1.22	8358
	1996	0	0	0	1	1	3	4	8	13	44	0.89	8283
	1997	0	0	0	0	1	1	4	7	9	27	0.66	8211
	1998	0	0	0	0	1	1	4	9	10	18	0.66	8204
	1999	0	0	0	0	1	1	3	7	10	28	0.64	8191
	2000	0	0	0	0	0	1	3	6	10	23	0.52	8348
	2001	0	0	0	0	1	1	4	7	10	23	0.74	8345
	2002	0	0	0	0	1	1	3	7	10	23	0.63	8254

Table 4.1.8 compares the seasonal TRS hourly Level A and B objective exceedances, for the periods before and after the major emission upgrades at the pulp mills. The seasonal pattern is similar at all monitored locations. Even though the number of hours of exceedance have decreased since emission reductions (1986-1989), the distribution of exceedances has remained similar. Occasionally, summer levels are higher than fall, reflecting the occurrence of inversions or stagnant conditions. The number of exceedances

recorded at a particular monitoring site is dependent on proximity to the emission sources, and meteorological conditions.

With the exception of 1998, the frequency of exceedance of TRS objectives has decreased since emission source changes were implemented in late 1990. The operation of foul condensate steam stripping, collection and incineration, which has reduced odorous emissions from the pulp mill effluent treatment ponds, are responsible for most of this reduction in exceedances. The Air Quality Plan calls for the identification of other reduction sources to further improve compliance with the air quality objectives, particularly in the downtown.

Table 4.1.8
Comparison of 2002 with Previous Rates of Seasonal Exceedances
of the TRS One-Hour Level A and B Objectives

Station / Season	1986-1989 Percent of Season*		1990-1993 Percent of Season*		1994-1998 Percent of Season*		1999 Percent of Season*		2000 Percent of Season*		2001 Percent of Season*		2002 Percent of Season*	
	> 7	> 28	> 7	> 28	> 7	> 28	> 7	> 28	> 7	> 28	> 7	> 28	> 7	> 28
Jail														
Winter	37.2	18.6	21.2	2.7	20.3	1.1	13.5	0.9	20.6	0.2	23.3	0.2	9.0	0.0
Spring	25.4	12.1	13.7	1.3	13.3	0.9	9.8	0.5	7.1	0.1	7.1	0.1	4.6	0.1
Summer	19.6	9.2	9.7	1.8	9.7	0.5	15.1	0.6	5.4	0	6.5	0.1	7.2	0.1
Fall	30.2	16.7	13.7	2.1	13.9	0.9	15.0	0.1	20.1	1.7	16.3	0.1	16.3	1.1
Plaza														
Winter	28.7	15.4	18.7	1.8	16.0	0.7	13.3	0.1	16.3	0.3	25.0	0.2	13.5	0
Spring	16.3	6.8	9.1	1.0	6.2	0.1	6.2	0.2	2.7	0	2.9	0	3.1	0
Summer	12.6	6.0	5.9	1.0	6.1	0.1	8.0	0.2	3.8	0	3.8	0	4.0	0
Fall	21.5	11.0	9.5	0.7	6.6	0.2	10.5	0.1	10.0	0.5	11.0	0	12.1	0.6
Lakewood														
Winter	9.2	2.4	6.9	0.1	7.6	0.1	5.0	0	5.8	0	9.4	0	4.2	0
Spring	1.9	0.2	1.1	0	0.8	0	0.6	0	0	0	0	0	0.5	0
Summer	1.3	0.2	0.3	0	0.2	0	0.7	0	0.1	0	0.2	0	0	0
Fall	5.6	1.0	2.6	0.1	1.3	0	2.0	0	1.7	0	2.4	0	1.5	0

* Assumes no missing data when calculating percent hours per season

For this analysis the seasons are defined as follows:

Winter; December, January, February
Spring, March, April, May
Summer; June, July, August
Fall; September, October, November

4.1.2 Comparison of TRS Levels with Other B.C. Locations

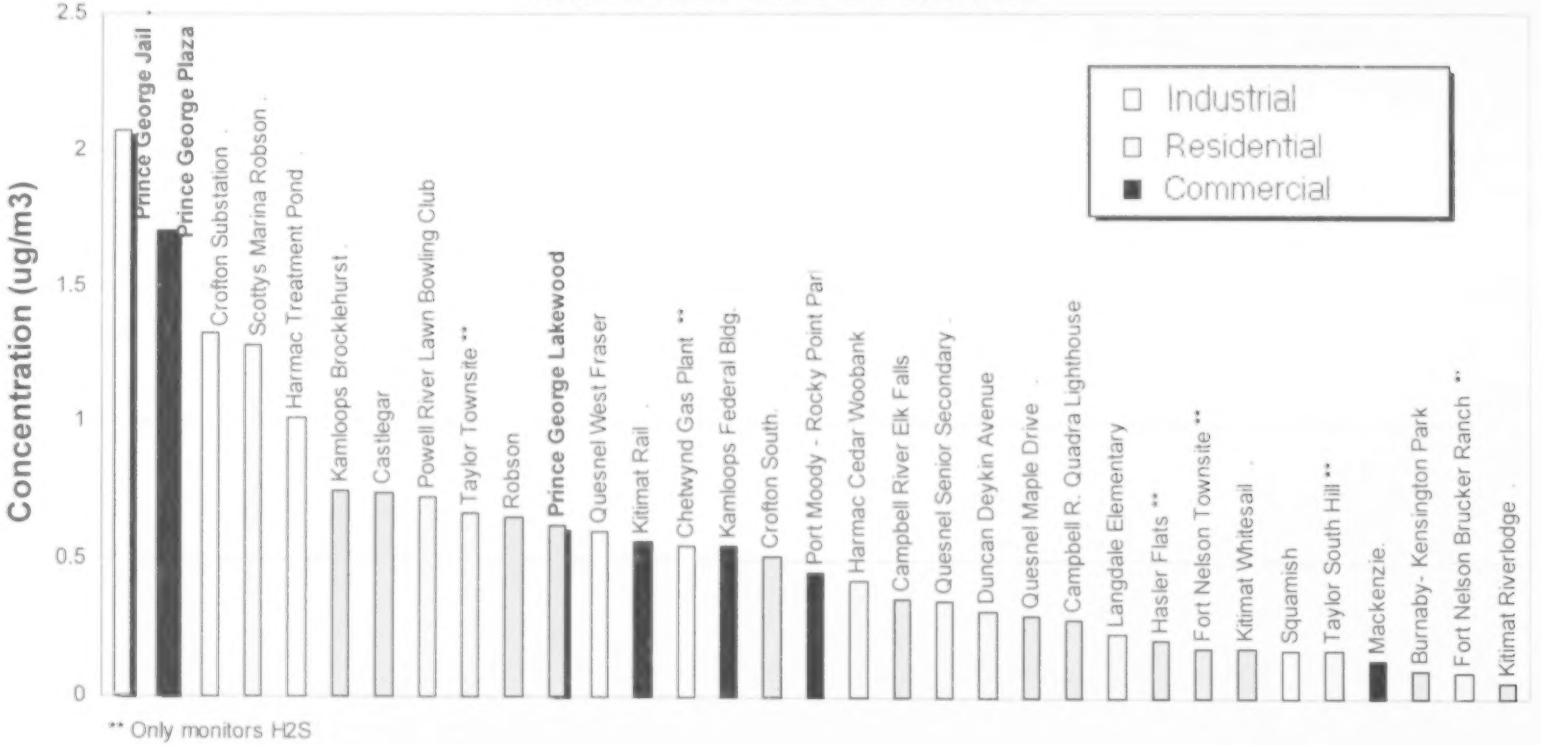
Figure 4.1.10 compares the TRS annual averages recorded in Prince George with those at other monitoring sites in B.C. (all sites with greater than 75% of data captured). Even though levels at the Jail have been decreasing over the past several years, this site recorded the highest annual average of all the monitored sites. The Plaza's commercial site recorded the second highest annual average, which was well above the Quesnel Industrial site. Lakewood recorded the seventh highest annual TRS average of the twenty-two B.C. residential sites, compared with the fourth position in 2001. In fact, in comparing all 30 sites that monitored TRS every year since 1996, Lakewood recorded the ninth highest compared to the seventh to sixteenth highest for the previous six years.

Several sites in northern B.C. only recorded H_2S (a component of TRS). Therefore, annual averages at those sites might have been higher if other components of TRS were present.

When comparing the same sites that monitored TRS in 2001, 23 out of the 36 monitoring sites recorded a decrease in 2002. Quesnel – West Fraser showed the biggest incremental decrease and Scotty's Marina Robson showed the biggest incremental increase. Three out of the four biggest incremental decrease occurred at the Quesnel sites. Plaza showed a slight increase in 2002 whereas Jail and Lakewood showed a decreased compared to 2001.

Figure 4.1.10

Comparison of 2002 Annual Average TRS Levels with Other B.C. Locations



** Only monitors H2S

4.2 Sulphur Dioxide (SO_2) Results

SO_2 is a colourless gas that has a pungent odour at concentrations above 900 $\mu g/m^3$ (Level B one-hour objective). SO_2 can adversely affect both human health and vegetation. Very high levels of SO_2 can cause breathing discomfort, respiratory illness, alterations in the lung's defenses, and aggravation of existing respiratory and cardiovascular diseases. Most people who are sensitive to SO_2 are asthmatics and individuals with chronic lung or cardiovascular diseases. Effects of SO_2 on vegetation depend on the plant species. Sensitive plant foliage can suffer acute or chronic injury.

SO_2 can be oxidized (either photochemically or in the presence of a catalyst) to sulphur trioxide, which in the presence of water vapour is readily converted to sulphuric acid mist. Sulphuric acid and other sulphates can account for about 5%-20% of the total suspended particulates in some urban airsheds. Many health problems attributed to SO_2 may be the result of the oxidation of SO_2 to other compounds. Only small amounts of SO_2 gas reach the lower respiratory tract, whereas acid aerosols such as sulphates can be carried into the deeper lung airways. Asthmatics have shown demonstrable health effects when exercising at SO_2 levels as low as 1000 $\mu g/m^3$ but are also sensitive to acid aerosol concentrations as low as 100 $\mu g/m^3$ (see Brimblecombe, 1996).

Emissions of sulphur also contribute to the production of acid rain, but this is not considered a problem in this area of the province. The pH of rainfall in the Prince George area is near normal, with a pH of 5.6 based on sampling over seven years starting in the late 1970's.

The current analyzers have a detection limit of 2.5 $\mu g/m^3$ (Fig 4.2.1). The analyzers measure the total amount of SO_2 gases by fluorescent excitation of SO_2 by ultra-violet radiation.

Fig 4.2.1 TECO SO2 Monitor

It was recognized in 1992 that with only one station measuring SO_2, it was likely that the highest ambient SO_2 levels were not being measured in the airshed. Results of dispersion modelling indicated potentially significant exceedances of ambient SO_2 levels at higher elevations in the Prince George area. Increased monitoring commenced in 1995 to evaluate the results of the modelling and to determine the need for source reductions.

The quality of the 2002 SO_2 data was found to range from excellent to satisfactory through monthly calibrations, and independent auditing in April and October (Table D-1, Appendix D). Audit results for the SO_2 monitor at Plaza was excellent in April and satisfactory in October whereas CBC was satisfactory in April and excellent in October. The monitor at the Jail was satisfactory for both April (6.2% deviation) and October (7.5% deviation) audits. Data quality is considered unsatisfactory if the monitor deviates by 15% or more. Data recovery was about 95% at all three sites.

The SO_2 data from the Jail, Plaza and CBC Transmitter sites are summarized in Tables 4.2.1- 4.2.3, respectively. Ambient SO_2 levels exceeded the Level A one-hour provincial

objective at all three sites. Both the Plaza and Jail sites recorded only one exceedance of the one-hour objective, but the CBC site recorded four Level A exceedances in 2002. There were no exceedances of the Level B hourly objective. Nor were there any exceedences of the 24-hour Level A objective at any of the monitoring sites.

Table 4.2.1
2002 Monthly Summary of SO_2 Data at Jail

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	>450$\mu g/m^3$	>900$\mu g/m^3$	($\mu g/m^3$)	>160$\mu g/m^3$	>260$\mu g/m^3$	($\mu g/m^3$)
January	10.7	0	0	200	0	0	71.9
February	9.8	0	0	165	0	0	55.3
March	19.8	0	0	178	0	0	81.0
April	8.7	0	0	125	0	0	47.4
May	13.8	0	0	240	0	0	84.7
June	13.8	1	0	519	0	0	87.4
July	9.4	0	0	200	0	0	55.1
August	10.3	0	0	322	0	0	54.3
September	8.9	0	0	232	0	0	66.9
October	8.6	0	0	149	0	0	62.4
November	12.1	0	0	208	0	0	63.9
December	12.9	0	0	218	0	0	62.5
Annual	**11.6**	**1**	**0**	**519**	**0**	**0**	**87.4**

Table 4.2.2
2002 Monthly Summary of SO_2 Data at Plaza

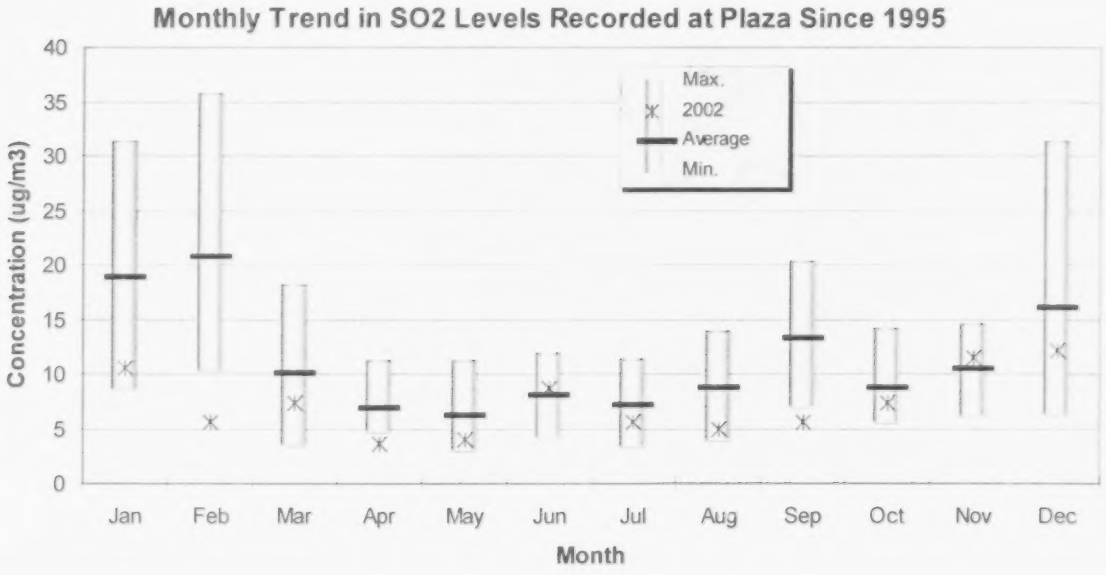
	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	>450$\mu g/m^3$	>900$\mu g/m^3$	($\mu g/m^3$)	>160$\mu g/m^3$	>260$\mu g/m^3$	($\mu g/m^3$)
January	10.5	0	0	213	0	0	68.1
February	5.6	0	0	115	0	0	38.2
March	7.4	0	0	157	0	0	36.8
April	3.6	0	0	112	0	0	17.3
May	4.0	0	0	85	0	0	23.5
June	8.6	1	0	527	0	0	50.3
July	5.6	0	0	208	0	0	35.2
August	4.9	0	0	96	0	0	23.1
September	5.6	0	0	200	0	0	34.2
October	7.3	0	0	197	0	0	43.0
November	11.5	0	0	136	0	0	60.5
December	12.2	0	0	205	0	0	55.7
Annual	**7.2**	**1**	**0**	**527**	**0**	**0**	**68.1**

Table 4.2.3
2002 Monthly Summary of SO_2 Data at CBC Transmitter

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	>450$\mu g/m^3$	>900$\mu g/m^3$	($\mu g/m^3$)	>160$\mu g/m^3$	>260$\mu g/m^3$	($\mu g/m^3$)
January	9.7	0	0	173	0	0	50.1
February	9.7	0	0	370	0	0	54.2
March	23.8	1	0	597	0	0	109.0
April	8.6	0	0	85	0	0	30.2
May	13.0	0	0	216	0	0	56.4
June	13.4	1	0	559	0	0	87.0
July	12.3	0	0	373	0	0	75.3
August	8.4	1	0	583	0	0	65.4
September	7.9	0	0	216	0	0	74.7
October	11.0	1	0	623	0	0	76.2
November	17.0	0	0	386	0	0	84.0
December	15.1	0	0	442	0	0	106.6
Annual	**12.5**	**4**	**0**	**623**	**0**	**0**	**109.0**

The Jail and CBC sites recorded the highest monthly concentrations during March. The highest monthly average recorded at Plaza was December. The highest hourly averages occurred in June at Plaza and Jail, and in October at CBC.

Figure 4.2.2



Figures 4.2.2 – 4.2.4 show the trend in monthly SO_2 values at the Plaza, Jail and CBC sites since 1995. Monthly averages at the Jail in 2002 were below normal for all months and at least for ten months at the Plaza and CBC sites. These lower levels were due to the higher monthly averages recorded prior to the implementation of the Sulphur Recovery Unit at Husky in 1997. Monthly averages in May and June at the Jail were only slightly below normal compared to all other months. This may be partially attributed to the additional repair work on the Sulphur Recovery Unit that took place beyond planned. The unit was somewhat later coming on line than anticipated due to this extended repair period. The lowest averages since 1995 were recorded for three months in 2002 at the downtown and CBC sites (February, April and September) and one month at the Jail site (February). Monthly averages at the downtown and CBC sites tend to be the highest during January and February, whereas at the Jail site the highest levels tend to occur in March.

Figure 4.2.3

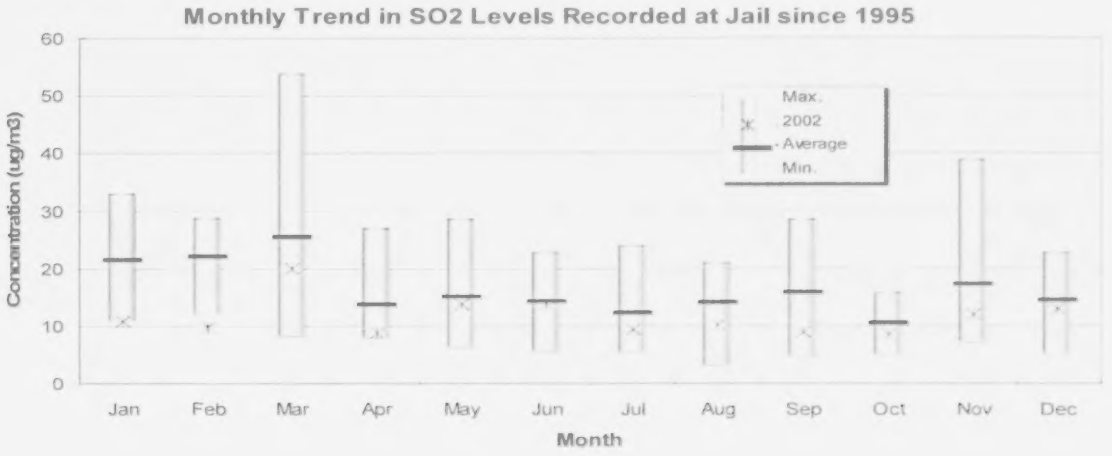


Figure 4.2.4

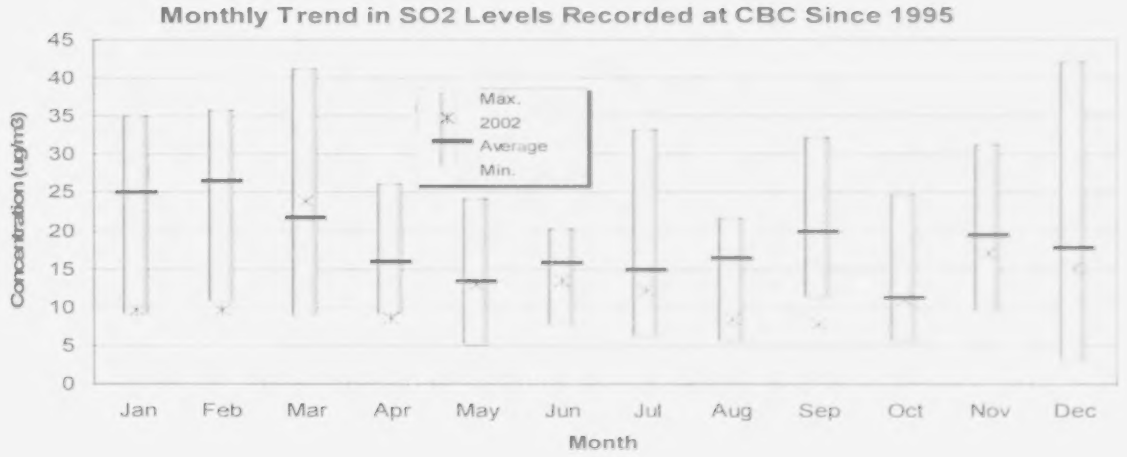


Figure 4.2.5 shows the SO_2 pollution rose for the Plaza site based on the 2002 meteorological data at that site. Wind directions were only considered when wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). Similar to that of the TRS pollution rose, the highest concentrations occurred with winds from the east even though the major sources are located northeast of this monitoring site. SO_2 levels were less than 4 $\mu g/m^3$ for about 12% of the time when the winds were blowing from the east, whereas with winds from the west-northwest, SO_2 levels were less than 4 $\mu g/m^3$ for 95% of the time. Also, SO_2 levels were greater than 25 $\mu g/m^3$ for 60% of the time during easterly winds, and levels above 50 $\mu g/m^3$ seem to occur only from the east-northest to southeast sector. Detectable SO_2 levels were recorded at almost all the 16 wind sectors. This may not be an indication of other sources, but a result of SO_2 levels building up in the area under calm conditions, and once wind speeds increase (from any direction) it takes time to flush these pollutants out of the airshed. However, a sulphuric acid plant located in the BCR Industrial Park may be the source for the higher frequency of SO_2 levels above 4 $\mu g/m^3$ from the southwest sector.

Figure 4.2.5: SO_2 Pollution Rose Recorded at Plaza for 2002

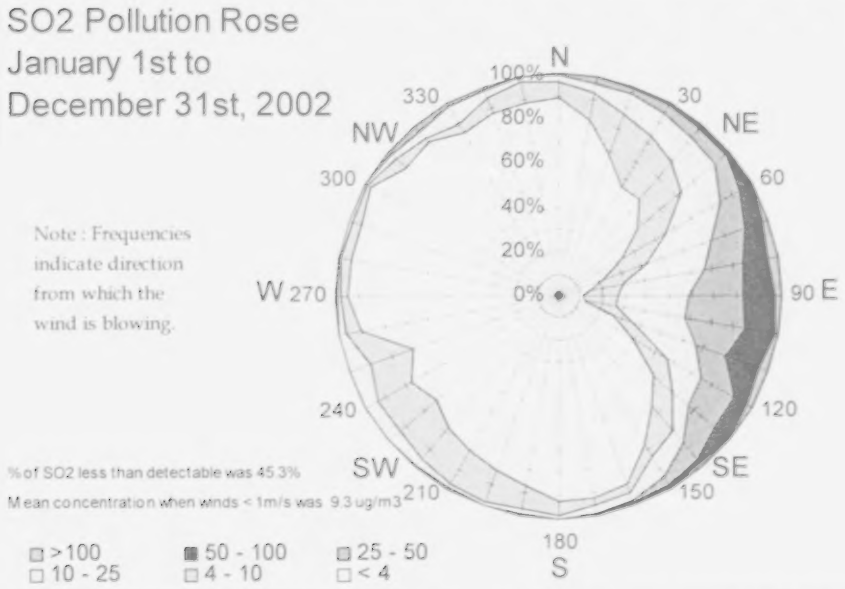
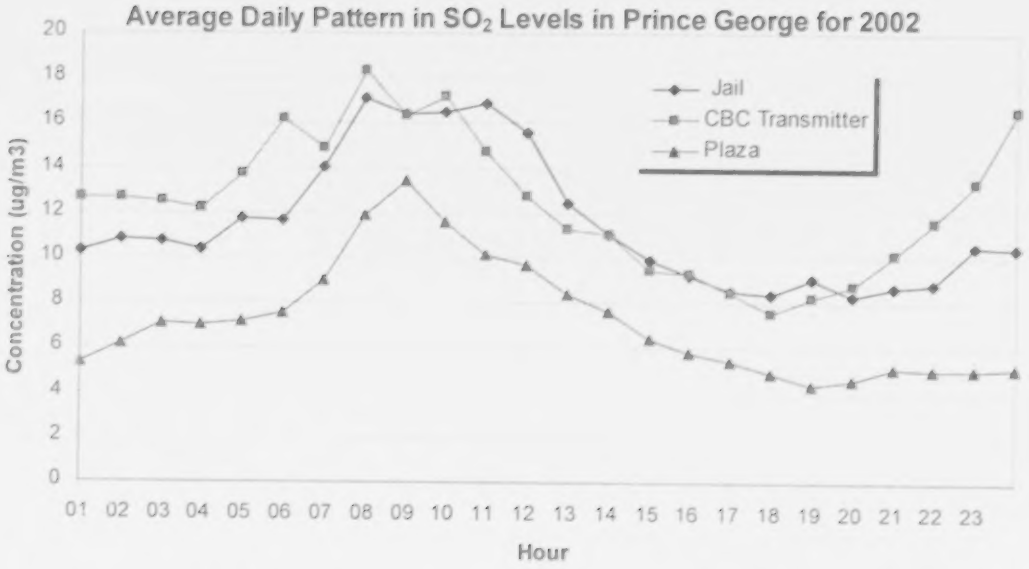


Figure 4.2.6 shows the average SO_2 concentrations in 2002 for each hour of the day for each monitoring site. This figure gives the average diurnal pattern of SO_2 levels that has been measured at each site. Unlike TRS, levels of SO_2 at Plaza generally do not increase in the evening, but start increasing in the morning. These high morning concentrations are due to a process known as fumigation. Levels build up overnight above the inversion layer, and once the inversion breaks due to daytime heating, this pollution is brought back to the valley surface. This pattern indicates that SO_2 is emitted from high stacks whereas TRS is emitted closer to the ground.

Figure 4.2.6



The CBC site also shows this fumigation pattern, but levels also started increasing late in the evening until midnight. This is due to the CBC being located at a higher elevation. The SO_2 emitted from the stacks gets trapped in the inversion that develops over the plateau, and levels increase at the CBC as the inversion strengthens. It is uncertain as to why levels at the CBC site started decreasing after midnight.

The Jail site is located at a lower elevation and also experiences fumigation and, on occasion the trapping processes. But both meteorological processes are not as noticeable as that at the Plaza and CBC sites. SO_2 levels are the lowest in the afternoon, at the CBC site, when mixing is at its greatest. In the afternoon levels at CBC are similar to those at the Jail but at night the levels at CBC are about 20% higher. This could be due to the trapping process affecting the higher elevations more.

4.2.1 SO_2 Annual Trends

Table 4.2.4 summarizes the SO_2 data collected at the Jail station from 1981 to 2002. Prior to 1986, data was obtained from a Philips SO_2 continuous analyzer which was subject to interference from various TRS compounds resulting in less accurate data. In 1986 the Philips analyzer was replaced with a TECO analyzer. The SO_2 average for 1986 is based upon Philips data for Jan. - Feb. and TECO monitor data for Mar - Dec. The lower annual averages for 1986 and 1987 are attributable to the improved quality of data provided by the new monitor.

The annual sulphur dioxide average recorded at the Jail in 1996 was the highest since the monitor was switched to the TECO analyser, and so was the frequency of exceedances of the hourly Level A objective. The contribution of SO_2 from industrial emissions increased significantly each year until 1997. These increases were caused predominantly by higher sulphur levels in the crude oil processed at the Husky refinery, as well as by increased TRS incineration at the pulp mills. From 1996-2000, the annual SO_2 average and frequency of hourly Level A exceedances at that site have been decreasing. But levels have again increased slightly in 2001 and 2002 which appears to be due to an increase in emissions from the Husky Refinery, since pulp mill emissions decreased marginally. Meteorological factors may also account for this variation.

With the new sulphur recovery unit installed at Husky in 1997, ambient SO_2 levels have decreased significantly in the airshed. Considerable reduction (greater than 50%) in annual average ambient SO_2 levels occurred at the Jail, Plaza, and CBC sites in 1999 (Tables 4.2.4, 4.2.5, and 4.2.6, respectively). The full impact of this reduction on air quality is noticeable from 1998 to 2002 (Figure 4.2.7). All three sites showed a gradual increase in levels since October 2000 although the levels were lower than those in the pre-sulphur recovery period. All three sites recorded at least one Level A hourly exceedance in 2002. No sites recorded a Level A daily exceedance. It is believed that the Jail site is affected more by Husky's flare than the CBC site. Prior to the implementation of the Sulphur Recovery unit at Husky ambient levels at both the CBC and Jail sites were fairly similar. After the unit was installed, levels at the Jail site were about 30% lower than those recorded at the CBC site which was due to the reduction in the frequency of flaring. From 1998-2000 emissions have decreased at Husky, but no consistent trend in pulp mill SO_2 has been reported. However, in 2001 there were increased emissions at Husky.

Annual averages in 2002 at all three sites were lower than that in 2001. A 4% decrease in the annual average ambient sulphur dioxide concentration from 2001 to 2002 was noted at the Jail monitoring station. But the downtown and CBC sites recorded a decrease of over 22%. SO_2 monitoring occurred in College Height from May 1995 to March 1999. During this period it was decided that SO_2 was not a concern at that site. Data for this site is recorded in Appendix E.

Table 4.2.4
Annual Trend Summary of SO_2 Data at Jail

Year	Annual Average ($\mu g/m^3$)	No. of 1-Hour Values >450$\mu g/m^3$	>900$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. of Daily Values >160$\mu g/m^3$	>260$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
1981	10.7	1	0	506	0	0	75.2	7,016
1982	25.5	1	0	719	0	0	161.4	6,535
1983	31.8	1	0	533	0	0	143.5	8,310
1984	22.9	6	1	1198	3	0	242.8	7,551
1985	21.0	0	0	399	0	0	119.3	7,860
1986*	16.9	4	0	538	0	0	152.5	8,278
1987	12.8	2	0	666	0	0	123.0	8,348
1988	13.8	8	0	586	1	0	173.8	8,412
1989	12.0	1	0	659	0	0	99.6	8,165
1990	5.5	0	0	283	0	0	56.7	6,719
1991	8.7	1	0	492	0	0	118.1	8,236
1992	12.1	1	0	450	0	0	104.0	8,363
1993	10.9	0	0	363	0	0	81.8	8,225
1994	12.5	1	0	469	0	0	123.0	8,162
1995	20.9	1	0	530	0	0	118.8	8,354
1996	24.1	10	0	734	2	0	189.6	8,368
1997	20.5	4	0	759	0	0	143.2	8,350
1998	18.6	1	0	469	0	0	129.0	7,580
1999	10.0	0	0	306	0	0	103.9	8,358
2000	9.0	0	0	415	0	0	96.3	8,362
2001	12.1	1	0	458	1	0	164.7	8,348
2002	11.6	1	0	519	0	0	82.3	8,367

* Philips analyzer was replaced with a TECO analyzer

Table 4.2.5
Annual Trend Summary of SO_2 Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. of 1-Hour Values >450$\mu g/m^3$	>900$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. of Daily Values >160$\mu g/m^3$	>260$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
1995	-	2	0	474	0	0	156.3	5,323*
1996	15.8	13	1	913	1	0	165.7	8,229
1997	14.6	8	0	663	0	0	118.3	8,363
1998	11.9	0	0	399	0	0	93.5	8,220
1999	7.2	1	0	490	0	0	105.3	8,703
2000	7.4	0	0	341	0	0	58.7	8,071
2001	9.5	1	0	455	1	0	173.0	8,340
2002	7.2	1	0	527	0	0	68.0	8,362

*Instrument installed May 1995

Table 4.2.6
Annual Trend Summary of SO_2 Data at CBC

Year	Annual Average ($\mu g/m^3$)	No. of 1-Hour Values >450$\mu g/m^3$	>900$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. of Daily Values >160$\mu g/m^3$	>260$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
1995	-	4	0	597	0	0	101.1	5,096*
1996	23.9	10	0	794	4	0	189.3	8,370
1997	20.1	9	0	778	2	0	197.7	8,312
1998	22.6	10	0	597	1	0	224.0	8,361
1999	13.0	11	0	751	1	0	227.1	8,560
2000	-	2	0	519	0	0	142.4	6,958
2001	16.2	10	1	969	4	0	193.7	8,347
2002	12.5	4	0	623	0	0	104.4	8,348

*Instrument installed May 1995

Figure 4.2.7

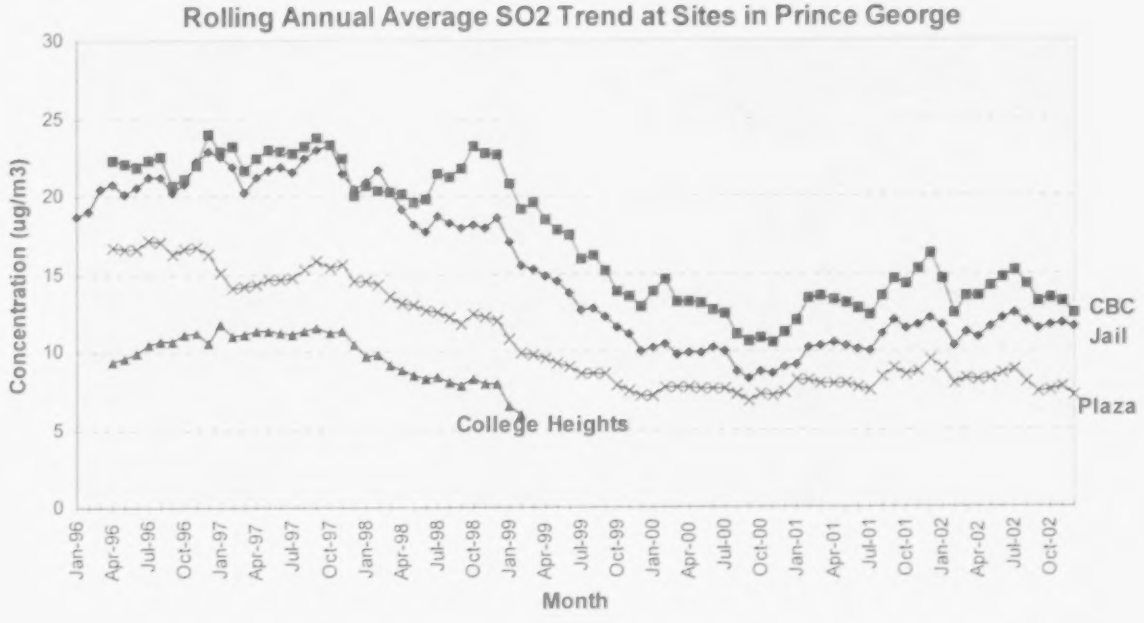


Table 4.2.7 shows the annual distribution of SO_2 percentiles for the past seven years. All three sites show a decrease in the frequency of higher levels in 1999-2000. The frequency of higher levels was greater in 2001 than in the previous two years at all sites, but still lower than the frequency before 1998. In 2002 the frequency of higher levels at the downtown and CBC sites were similar to those in 2000. Prior to 1997, the downtown site had levels over 150 $\mu g/m^3$ for at least 1% of the time. After 1998, levels were only half

that for the same percent of time. However, there was no noticeable decrease in the lower percentiles mainly because levels were near detectable for over half the time. The 75th percentile showed no decreasing trend at the Plaza site but did for the other two sites, thus indicating the influence of the Husky emissions on the higher elevation.

The annual trends in SO_2 demonstrate the effect of emissions from higher elevation stack sources at the surface of the valley. Even though the refinery emissions are discharged well above the valley floor with substantial plume rise, a reduction in ambient levels consistent with source reduction demonstrates the effectiveness of thermal inversions and subsequent fumigation at transferring these emissions to the valley floor.

Table 4.2.7
Percentiles of 1-hour SO2 Levels Recorded at the Three SO_2 Monitoring Sites

Pollutant	Station	Percentile (µg/m³)									Max. (µg/m³)	Average (µg/m³)	No. of Samples
		20	25	40	50	75	90	95	98	99			
Plaza													
	1995	0	0	0	3	8	35	67	115	176	474	13.26	5323
	1996	0	0	0	3	8	43	81	151	217	912	16.02	8232
	1997	0	0	3	3	11	37	72	125	182	663	14.62	8364
	1998	0	0	3	3	8	35	61	99	135	399	11.94	8220
	1999	0	0	0	3	5	19	35	61	83	490	7.19	8304
	2000	0	0	0	3	8	21	35	59	77	341	7.35	8071
	2001	0	0	0	3	8	27	45	77	111	455	9.47	8340
	2002	0	0	0	3	5	19	37	59	77	527	7.25	8362
Jail													
	1996	0	0	0	3	16	78	138	210	269	734	24.12	8378
	1997	0	0	3	3	16	61	112	184	224	759	20.49	8350
	1998	0	0	3	3	19	59	93	144	181	469	18.59	7580
	1999	0	0	0	3	5	29	56	91	123	306	10.02	8358
	2000	0	0	0	0	8	27	48	80	104	415	9.03	8362
	2001	0	0	0	3	8	37	64	104	128	458	12.06	8348
	2002	0	0	0	0	8	40	64	99	123	519	11.59	8367
CBC													
	1996	0	0	0	3	19	77	136	218	255	793	23.89	8372
	1997	0	0	3	3	13	56	101	178	242	778	20.12	8320
	1998	0	3	3	5	19	59	109	202	275	597	22.65	8361
	1999	0	0	0	3	5	35	69	123	192	751	13.04	8204
	2000	0	0	0	0	8	35	61	109	160	519	11.61	6958
	2001	0	0	0	0	11	45	88	162	237	969	16.18	8347
	2002	0	0	0	0	8	37	64	109	157	623	12.52	8348

4.2.2 Comparison of SO_2 Levels with Other B.C. Locations

Figure 4.2.8 compares the SO_2 annual averages recorded in Prince George with those at other monitoring sites in B.C. (only sites with greater than 75% of data captured). The highest annual average was measured at Trail Butler Park, which was twice as high as most other SO_2 monitoring sites. The CBC and Jail sites recorded the sixth and eighth highest SO_2 annual averages, respectively out of the 37 sites in B.C. All other sites with annual averages higher than the Jail were located in Trail. The Plaza site rated fourth among the commercial sites, behind Trail-Downtown, Trail-Hospital and Vancouver Robson Square sites. It should be noted that some of the monitors in Trail had a higher detection limit (MDL = 10 ppb (26 $\mu g/m^3$)) than the monitors located elsewhere.

When comparing the same sites that monitored SO_2 in 2001, 19 out of the 35 sites recorded a decrease in 2002. This decrease is likely due to a combination of emission and meteorology because no given geographical region showed an overall increase or decrease. The Prince George CBC site recorded the second biggest incremental decrease in annual averages out of all sites. Port Alice showed the biggest decrease in 2002, but showed the biggest increase in 2001. Trail-Downtown showed the biggest incremental increase in 2002 but Kitimat-Whitesail showed the biggest percent increase.

Figure 4.2.8

Comparison of 2002 Annual Average SO2 Levels with Other B.C. Locations
Concentration (ug/m3)
0
5
10
15
20
25
30
35
Industrial
Residential
Commercial
Trail Butler Park
Trail Downtown
Trail Hospital
Trail - West
Trail Warfield
Prince George CBC Trans.
Trail Genelle
Prince George Jail
Chetwynd Gas Plant
Vancouver - Robson Square
Kitimat Haul Road
Port Alice Trailer
Trail Columbia Gardens
Prince George Plaza 400
Port Alice Lake Road
Vancouver - Kitsilano
Port Moody - Rocky Pt. Park
Port Alice Rumble Beach
Robson
Burnaby - Kensington Park
North Vancouver - Mahon Park
Taylor Townsite
Kitimat Rail
Victoria Topaz
Pitt Meadows Elementary School
Richmond South
Abbotsford
Langdale Elementary
Kamloops Federal Building
Taylor South
Kitimat Whitesail
Squamish
Kamloops Brocklehurst
Fort Nelson Brucker Ranch
Fort Nelson Townsite
Hasler
Kelowna College

4. 3 Nitrogen Dioxide (NO_2) Results

The atmosphere contains approximately 78% nitrogen and 21% oxygen by volume. Of the five major forms of gaseous nitrogen in the atmosphere, nitrogen (N_2), ammonia (NH_3), nitrous oxide (N_2O), nitrogen dioxide (NO_2), and nitric oxide (NO), the latter two are monitored in Prince George.

Nitric oxide (NO) is formed during high temperature combustion of nitrogen and oxygen gases, primarily from motor vehicle exhaust and stationary combustion (such as industrial processes, waste incineration, and fuel combustion for heating homes and buildings). Emissions of NO are greater during winter months when use of heating fuels increases. Natural sources of NO include lightning and soil bacteria.

Nitric oxide is easily oxidized to NO_2 (a reddish-brown gas with a pungent and irritating odour at concentrations over 250 $\mu g/m^3$) by combining with ozone or certain hydrocarbons. Nitrogen dioxide in the presence of sunlight then produces ozone. The NO_2 absorbs short wave blue light, leaving longer wavelengths that cause it to appear reddish-brown, thereby contributing to the degradation in visibility. Higher incidents of eye irritation and respiratory health problems occur during smog-like conditions. The effects of short-term exposure of NO_2 are unclear, but frequent exposure to concentrations higher than those normally found in the ambient air may increase acute respiratory diseases in children (see Brimblecombe, 1996). Extremely high concentrations of NO_2 (> 2000 $\mu g/m^3$) can cause both reversible and irreversible effects arisen from structural changes in cells in the respiratory system (Ibid.). Unlike SO_2, NO_2 can penetrate directly to the pulmonary region of the lungs (see Stern et. al.). NO_2 also degrades material such as metals, fabrics, and rubber and has an adverse effect on vegetation. Only rarely at extremely high concentrations of NO is there visible foliar injury. However, NO_2 can cause vegetation injury at concentrations as low as 160 ppb (300 $\mu g/m^3$) or even lower concentrations when combined with SO_2 or O_3 (see Bytnerowicz et. al., 1998). Mixtures of air pollutants occur more frequently in the ambient air than a single pollutant. Various scenarios of the effects of pollutant mixtures can take place. For instance, it has been demonstrated that SO_2 can lower the threshold for damage by NO_2. The presence of SO_2 can inhibit potential means of detoxification of NO_2 products.

Generally, NO_2 reacts with water to form nitric acid, a component of acid rain. The transformation of NO_2 to nitric acid is much more rapid than that of SO_2 to sulphuric acid. Acidification also produces acid aerosols (nitrates) which have been measured in this airshed and is provided in Appendix E-4.1.

The current analyzer (Fig. 4.3.1) has a detection limit of 2.5 $\mu g/m^3$. Monitoring of nitric oxides is based on the principle of chemiluminescence involving a gas phase reaction of NO and ozone. For NO_2, the gas is passed through a catalytic converter where NO_2 is reduced to NO. The total concentration of NO is then treated as oxides of nitrogen (NO_x). The difference between the two measurements is considered to be NO_2.

Fig 4.3.1 Chemiluminescence NOx Monitor

The quality of NO_2 data at Plaza was found to be satisfactory through monthly five-point calibrations, as well as independent auditing in April and October (Table D-1, Appendix D). The percent valid data for the year was 93.3%, which is acceptable by Ministry standards for assessing annual trends and compliance with air quality objectives.

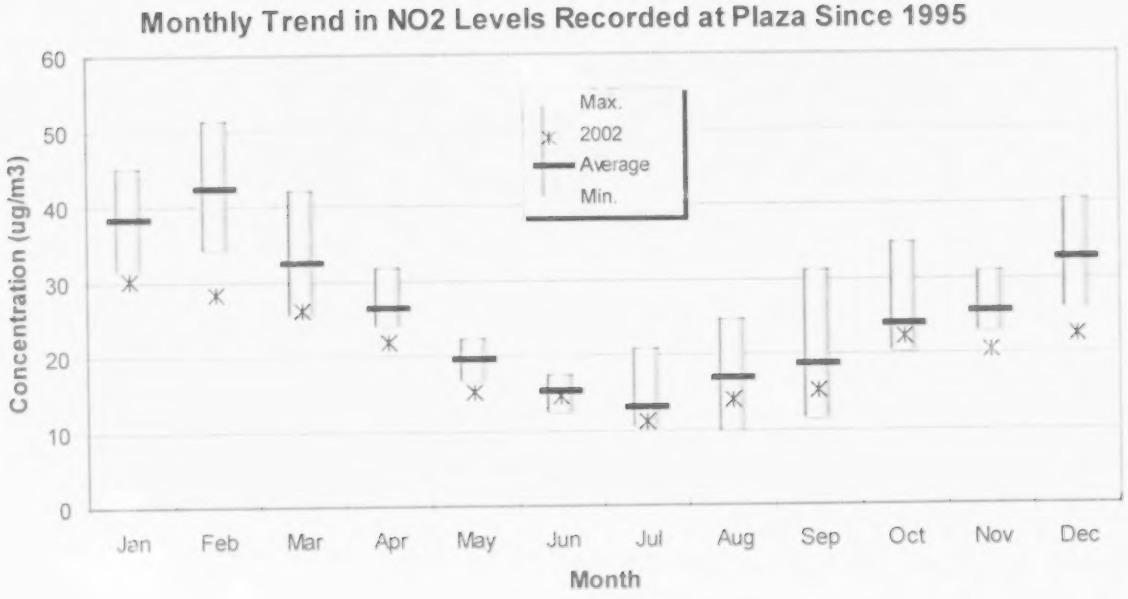
The nitrogen dioxide data from the Plaza site is summarized in Table 4.3.1. Ambient NO_2 levels were well within the provincial objectives with no Level A hourly or daily exceedances. The highest monthly averages at Plaza occurred in the winter (Jan.- Mar.), with the maximum monthly average in January. This is expected because inversions tend to be stronger during winter, there are additional sources (i.e., increase use of heating fuels) in winter, and during winter there is less solar radiation to promote the breakdown of NO_2 to NO, which causes NO_2 levels to build up in the troposphere.

Table 4.3.1
2002 Monthly Summary of NO_2 Data at Plaza

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. Of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	>400$\mu g/m^3$	>1000$\mu g/m^3$	($\mu g/m^3$)	>200$\mu g/m^3$	>300$\mu g/m^3$	($\mu g/m^3$)
January	30.2	0	0	138	0	0	75.1
February	28.3	0	0	86	0	0	75.1
March	26.1	0	0	103	0	0	74.1
April	21.8	0	0	75	0	0	39.4
May	15.2	0	0	71	0	0	28.2
June	14.5	0	0	84	0	0	31.5
July	11.0	0	0	59	0	0	23.1
August	14.0	0	0	59	0	0	27.3
September	15.2	0	0	52	0	0	27.8
October	22.2	0	0	88	0	0	40.7
November	20.5	0	0	75	0	0	46.7
December	22.5	0	0	105	0	0	63.9
Annual	**20.2**	**0**	**0**	**138**	**0**	**0**	**75.1**

Figure 4.3.2 shows the range in the monthly NO_2 levels at the downtown location since 1995. Data collected prior to 1995 was not used because the method used to archive that data could result in slightly lower monthly averages than expected. This figure shows that the highest levels tend to occur in January and February and the lowest in July. All months in 2002 recorded NO_2 levels that were lower than the average. Six months in 2002 recorded the lowest levels ever recorded for those months.

Figure 4.3.2



Figures 4.3.3 and 4.3.4 show the NO_2 and NO pollution roses, respectively, for the Plaza site based on the meteorological data for 2002. Wind directions were considered whenever wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). With the limited data available, almost one quarter of the NO values (22.5%) were below detectable, whereas only about one-eighth of the NO_2 values (13%) were below detectable. This is probably due to NO reacting with other pollutants such as ozone and quickly being converted to NO_2. This would indicate that most of the NO_2 in the Prince George airshed is a secondary pollutant (i.e., derived from NO from local sources), since it is estimated that about 10% of the NO_x from stacks is emitted as NO_2 and the remaining 90% as NO. Also, under wind conditions < 1 m/s, the average NO_2 concentration was about 37.8 $\mu g/m^3$, which was about 73% of the total NO_x concentration under the same conditions.

These pollution roses show that the higher concentrations of both NO_2 and NO originated from a number of wind directions, not from one sector predominantly as shown for TRS and SO_2. This indicates that the major sources of NO_x are dispersed throughout the airshed. Both roses show somewhat higher frequency of the higher concentrations from easterly sources, which likely indicates contributions from the industrial sources in that area, and possibly rail locomotive traffic. Higher concentrations also originated from the southwest to west direction, which likely indicate contributions from the BCR industrial site and rail locomotives, as well as motor vehicles and space heaters. Similar to the SO_2 pollution rose, low concentrations seldom occurred (less than 20%) when winds blew from the east, that often occurred (about 75%) from the south to south-southeast direction.

Figure 4.3.3: NO_2 Pollution Rose Recorded at Plaza for 2002

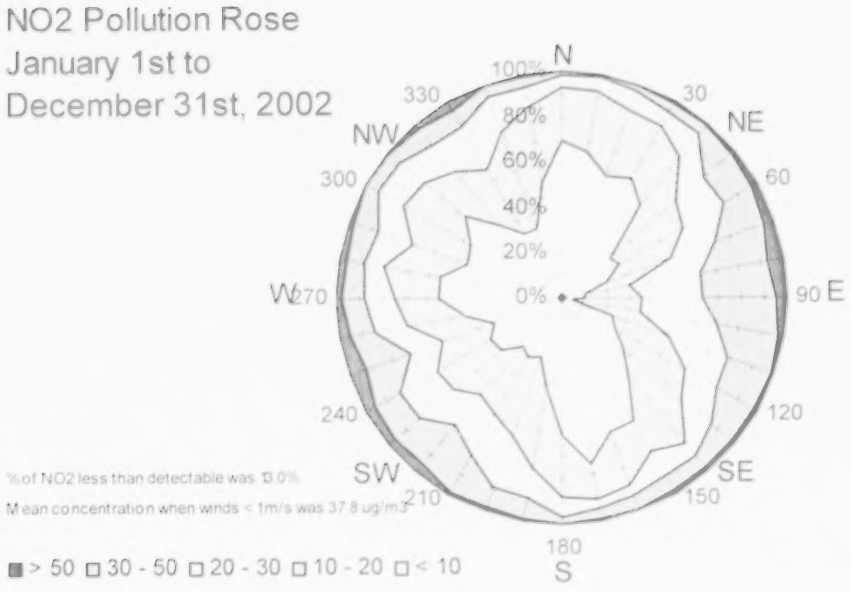
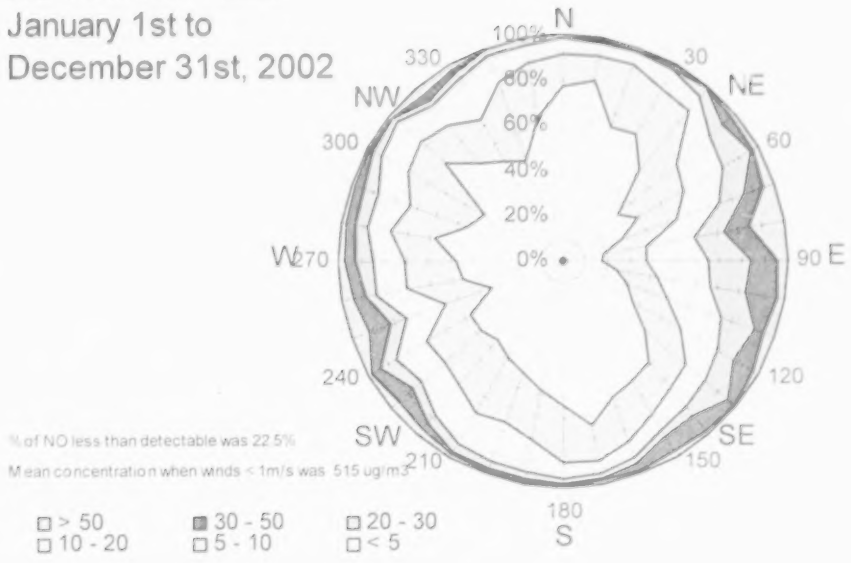


Figure 4.3.4: NO Pollution Rose Recorded at Plaza for 2002



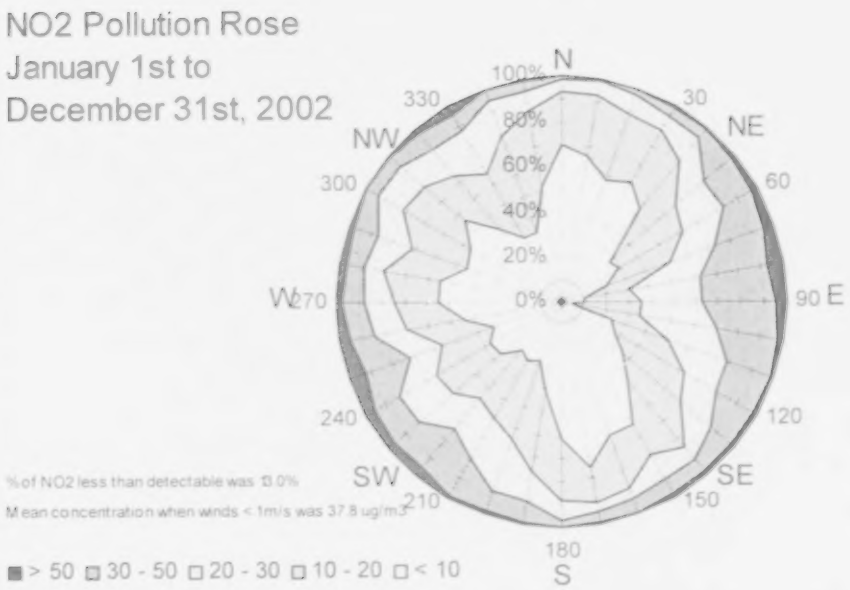
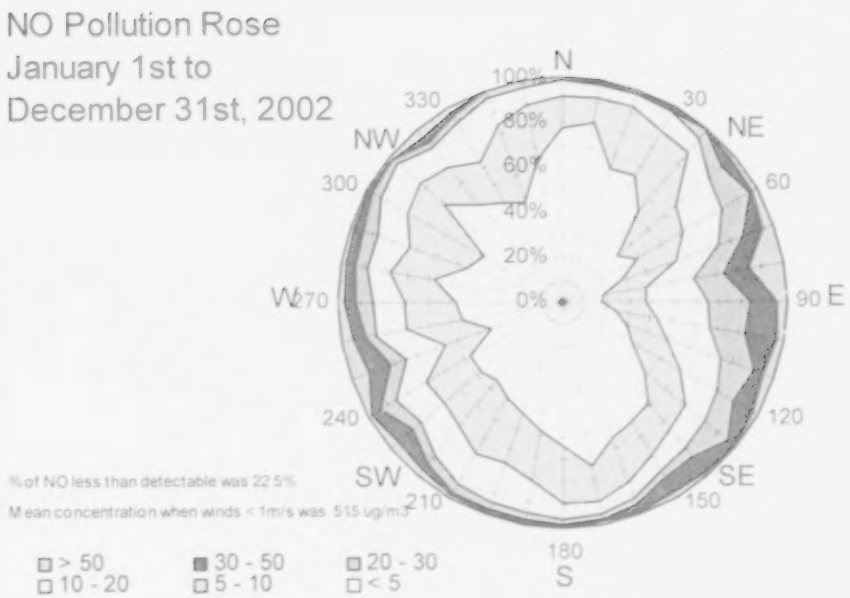


Figure 4.3.4: NO Pollution Rose Recorded at Plaza for 2002



Figures 4.3.5 and 4.3.6 show the typical diurnal patterns of NO_2 and NO, respectively, that were expected during specified times of the year in 2002. All months were analysed but only selective months are shown. Both figures show higher levels in the evening and morning and lower levels in the afternoon during all months. However, the typical pattern for the morning peak is more noticeable for NO and is also more noticeable during the winter months. These peaks may not be due to rush hour traffic as typically seen in major cities, but due to fumigation from industrial sources similar to that shown in the SO_2 section. These peaks occur later during winter days than in summer days, indicating a later inversion breaking up in winter than in summer. NO_2 levels in May peak just after midnight and then decreased until morning. This may be due to NO reacting with ozone at night to produce NO_2. This NO_2 then slowly reacts with other compounds causing the NO_2 levels to decrease.

Figure 4.3.5

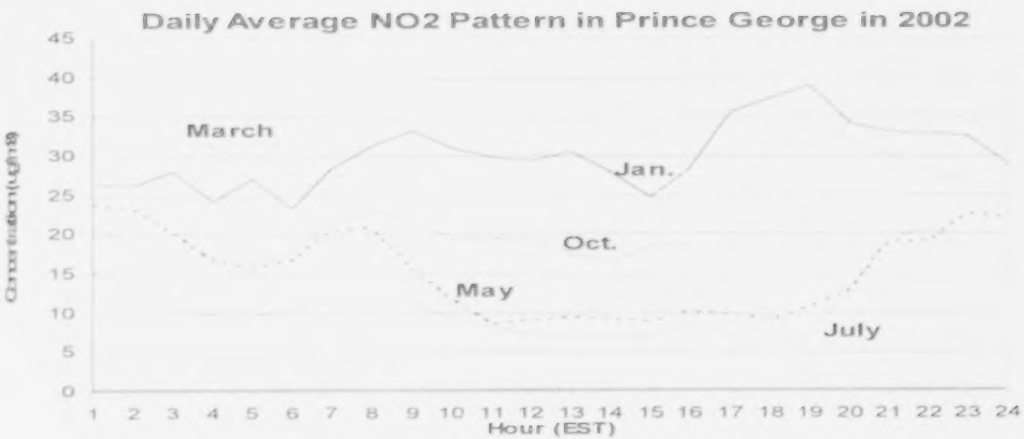
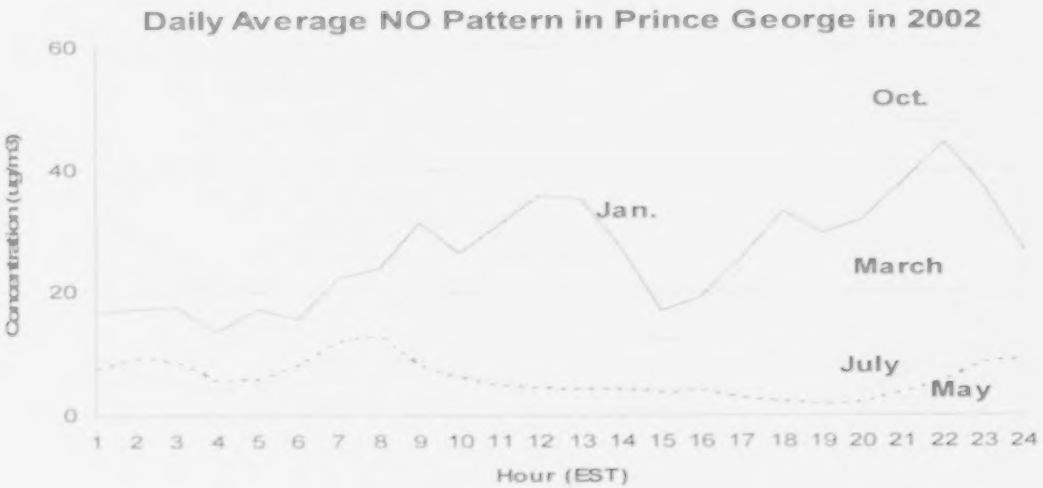


Figure 4.3.6



Both figures show that the highest afternoon levels occurred during January. However levels at night were higher in March for NO_2 and in October for NO. The lowest levels for both NO and NO_2 tend to occur during the summer. NO levels in May are lower similar to those in July, whereas for NO_2 levels in May are higher, especially at night or early morning. The NO_2 levels recorded in July were similar to the NO levels for that month, but the NO_2 levels recorded in May were about three times higher than the NO levels in that month.

Depending on the season the ratio of NO_2/NO can vary considerable, and the maximum and minimum ratios occur at different times of the day. During the winter the minimum ratio usually occurs during the late evening and the maximum late at night. During the summer (May-Sept.) the minimum ratio usually occurs during the morning and the maximum in the early evening. The ratio of NO_2/NO in January ranges from 0.7 in late evening to 1.7 late at night. In May, this ratio ranges from 1.6 in the morning to a high of 7.1 in the evening. This ratio changes again in September to range from a low of 0.7 in the morning to 3.0 in the evening.

4.3.1 NO_2 Annual Trend

Table 4.3.2 and Figure 4.3.7 summarize the NO_2 data collected at Plaza. Since late 1998 there seems to be a decreasing trend in annual NO_2 levels in the Prince George airshed. The average levels in 2001 and 2002 were the two lowest ever recorded at this site. It is uncertain as to why levels were the lowest in 2001 and 2002, but it should be noted that the monitor was replaced in January 2001. This should not affect the averages because monthly calibrations and annual audits showed that both monitors were working well, except for the last audit on the original NO_x monitor. The highest annual average occurred in 1998. The maximum daily average was recorded in December 1999. So far there have been no exceedances of the provincial NO_2 objectives at Plaza. The maximum hourly value, 186 $\mu g/m^3$, occurred on Jan. 2, 1997.

Figure 4.3.7

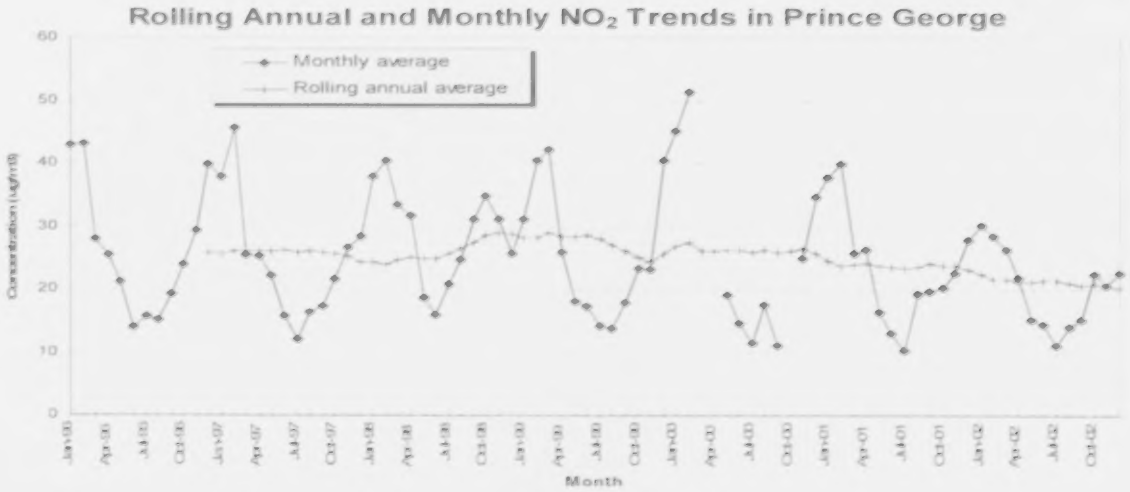


Table 4.3.2
Annual Trend Summary of NO_2 Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. of 1-Hour Values		Maximum Hourly Average ($\mu g/m^3$)	No. of 24 Hour Values		Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
		>400$\mu g/m^3$	>1000$\mu g/m^3$		>200$\mu g/m^3$	>300$\mu g/m^3$		
1992*	-	0	0	61	0	0	97.0	4,825
1993	25.4	0	0	149	0	0	83.3	8,072
1994	23.7	0	0	130	0	0	70.7	7,852
1995**	-	0	0	101	0	0	61.5	4,957
1996	25.9	0	0	151	0	0	84.6	7,787
1997	24.3	0	0	186	0	0	91.5	8,242
1998	28.7	0	0	143	0	0	67.1	8,051
1999	25.6	0	0	143	0	0	99.1	8,218
2000**	-	0	0	149	0	0	81.9	5,070
2001	23.0	0	0	111	0	0	81.5	8,295
2002	20.2	0	0	138	0	0	75.1	8,176

* Note: NO_2 TECO Analyzer Installed in June 1992
** Note: NO_2 Analyzer Operational Problems

Figure 4.3.7 shows that the rolling annual average has ranged from about 20 $\mu g/m^3$ to 29 $\mu g/m^3$ since 1996. Levels seem to be gradually decreasing since 1999. Monthly averages show that the highest levels occurred during the winter, and the lowest in summer. As previously explained, this difference is likely due to increased emissions in winter, favourable meteorological conditions and reduced solar radiation. Since November 1998 NO_2 levels have been gradually decreasing .

Table 4.3.3 shows the annual percentiles of both the NO_2 and NO values for the past seven years. Because NO_2 is seasonally influenced, and there were several periods of data missing in 1995 and 2000, it is not possible to compare that data with other years (even though data is provided in the table). For the six years of complete data there seems to be a decrease in most of the percentiles for NO_2. NO_2 and NO levels in 2002 were lower at all percentiles compared to all other years. All years with over 7800 hours of valid data recorded NO_2 levels less than 36 $\mu g/m^3$ 75% of the time, except for 1998 when levels were less than 40 $\mu g/m^3$ at the 75^{th} percentile. Peak levels occurred marginally less frequently in 1998 compared to any other years from 1996 -2000 (i.e., 98^{th} percentile in 1998 was 77 $\mu g/m^3$ compared to 78-88 $\mu g/m^3$ in 1996 to 2000). NO levels in 1998 were higher at all percentiles compared to all other years except for the 99^{th} percentile.

Table 4.3.3
Percentiles of 1-hour NO_2 and NO Levels Recorded at Plaza

Year	Percentile ($\mu g/m^3$)									Max. ($\mu g/m^3$)	No. of Samples
	5	10	25	50	75	90	95	98	99		
NO2											
1995	4	6	11	23	38	54	61	75	80	101	5182
1996	4	6	10	19	36	55	69	82	92	151	7800
1997	2	4	10	19	34	52	63	78	88	186	8243
1998	4	6	13	25	40	57	67	77	83	143	8051
1999	4	6	10	19	34	56	71	84	94	143	8218
2000	2	4	10	19	36	56	71	88	99	149	5070
2001	2	4	10	17	33	50	61	75	82	111	8295
2002	2	4	8	15	29	42	54	65	75	138	8176
NO											
1995	-	-	<22	<22	22	55	87	144	187	344	5188
1996	0	1	3	7	24	61	100	162	206	440	7778
1997	0	0	3	8	24	59	97	168	243	544	8181
1998	1	1	4	10	30	74	119	182	241	566	8074
1999	0	1	4	9	24	57	87	126	170	479	8226
2000	0	1	4	9	26	66	110	182	236	447	5070
2001	0	1	3	6	19	51	87	145	189	497	8294
2002	0	1	3	6	18	42	72	120	166	530	8175

4.3.2 Comparison of NO_2 Levels with Other B.C. Locations

Figure 4.3.8 and 4.3.9 compare the NO_2 and NO annual averages recorded at the Plaza monitoring site with those at other selected monitoring sites in B.C. (all sites with greater than 75% of data captured).

In 2002, there were 25 NO_2 monitoring sites located in B.C. but, only seven outside the Greater Vancouver Regional District. The 14 highest NO_2 levels were all recorded in the Greater Vancouver Regional District, which has been the case in previous years. Prince George recorded the highest annual average out of all the sites located outside the Greater Vancouver Regional District. For NO, there were 13 sites in the Greater Vancouver Regional District that recorded higher annual averages than that at Plaza. Victoria recorded the highest annual average out of all sites located outside the Greater Vancouver Regional District.

When comparing the same sites that monitored NO_2 in 2001, 13 of the 23 sites recorded a decrease in 2002. Since these 13 sites are located at varies sites across the province and not in one general area, this decrease is likely due to meteorology rather than increased emissions. Prince George showed the biggest decrease and Langley showed the biggest increase. For NO, there were eight sites that showed a decrease in 2002 compared to 2001. Prince George showed the second biggest incremental decrease and Pitt Meadows showed the biggest incremental increase.

Figure 4.3.8

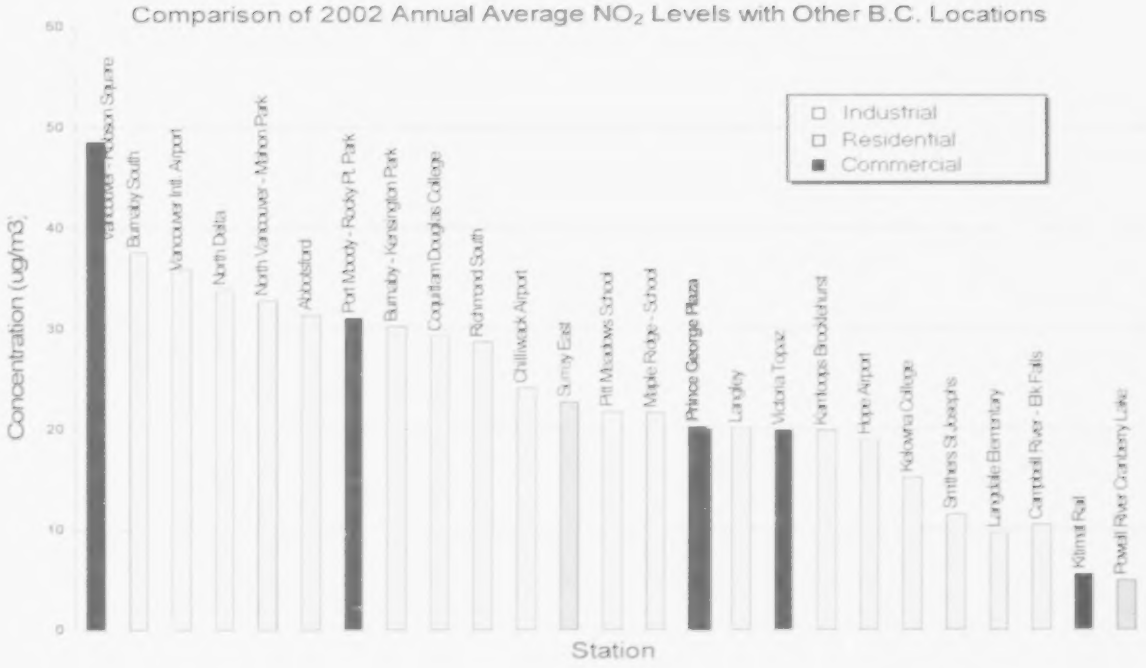
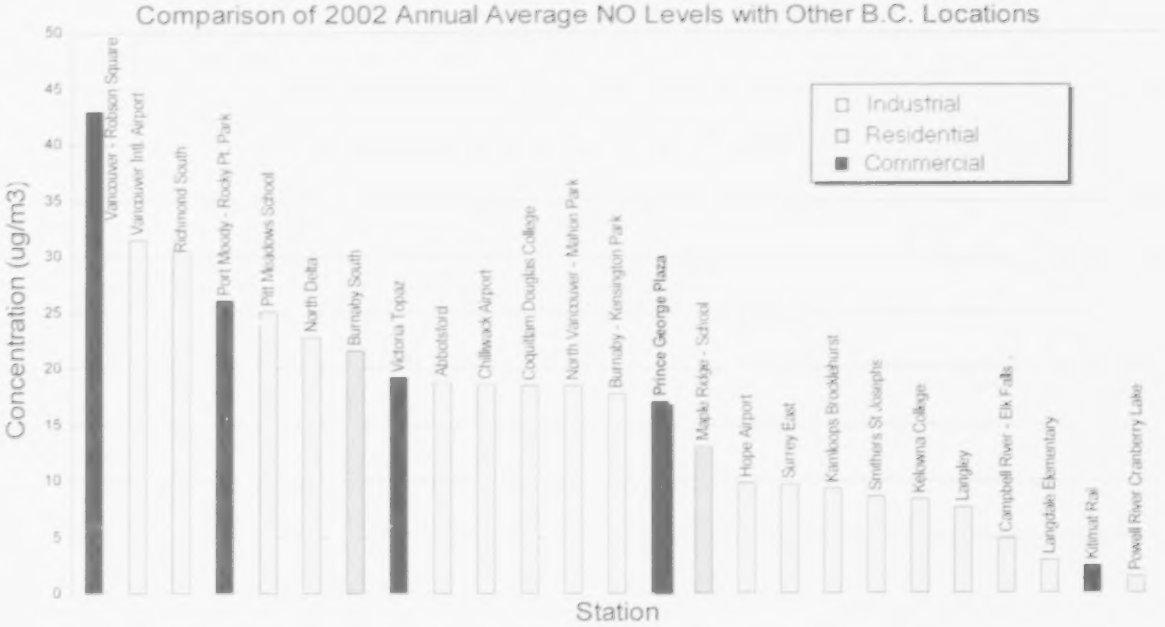


Figure 4.3.9



4.4 Ozone (O_3) Results

Ground level ozone is termed a secondary pollutant because it is not directly emitted into the atmosphere in significant amounts. It is photochemically produced through a complex series of chemical reactions involving oxides of nitrogen and volatile hydrocarbons in the presence of sunlight. Because of this, ozone tends to form downwind of industrial sources and can be produced by local, as well as long-range precursor sources. Other pollutants generated by these chemical reactions may include oxygen, nitrogen dioxide, nitric oxide, ketoses, aldehydes, and peroxyacetyl nitrates (PAN).

Ozone is a pulmonary irritant that affects respiratory function. Exposure to ozone results in clinical symptoms such as chest tightness, coughing and wheezing (see Ontario Ministry of Environment and Energy, 1995). It causes eye and throat irritation, thoracic pain, and is known to increase mucous production. Long term exposures to ozone present the possibility of irreversible changes in the lungs, which could lead to premature ageing of the lungs and/or chronic respiratory illnesses. It also accelerates the ageing of many materials, resulting in cracking of rubber or fading of dyes and paints (Ibid.). Injury to vegetation is one of the earliest signs of photochemical air pollution. Visible signs of these injuries are flecking and discolouration of the leaves. Ozone can also impair photosynthesis at low concentrations and result in reduction of crop yield. Short-term exposures to relatively high concentrations (> 300 $\mu g/m^3$) generally result in acute visible foliar injury (see Krupa, et. al., 1998). Long term chronic exposures to lower concentrations (100 – 160 $\mu g/m^3$) can cause physiological alterations that may result in chlorosis, premature senescence, and in growth and yield reductions (Ibid.).

There is only one ozone monitor in Prince George. An API Model 400 Ozone monitor (Fig. 4.4.1) was installed at Plaza in late April 1995. This analyzer has a detection limit of 1.2 $\mu g/m^3$. Monitoring of ozone is based on the absorption of (UV) ultra-violet light (wavelength at 254 nanometres) due to an internal electronic resonance of the ozone molecule. Ozone is a very efficient absorber of UV light, which is demonstrated by the fact that the stratospheric ozone protects life on earth from harmful UV radiation from the sun.

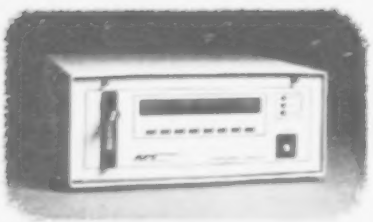


Fig 4.4.1 API Ozone Monitor

The quality of 2002 ozone data at Plaza was satisfactory based on the monthly calibrations as well as annual independent auditing in April and October (Appendix D). After quality assurance and quality control was applied to the data, there was 98.1% valid data in 2002.

Table 4.4.1 summarizes the ozone data from Plaza in 2002. The maximum one-hour level (128 $\mu g/m^3$) was recorded in May and June, while the 24-hour (102 $\mu g/m^3$) maximum occurred in April. Maximum hourly levels are normally expected between May to August, since these months have the longest hours of daylight, and solar radiation is normally at its maximum (Figure 4.4.2). Any exceedances of the one-hour Level A objective would be expected to occur between the months of March and September. Exceedances of the 24-hour Level A objective can occur during any month, as there is some evidence that this objective is below the background

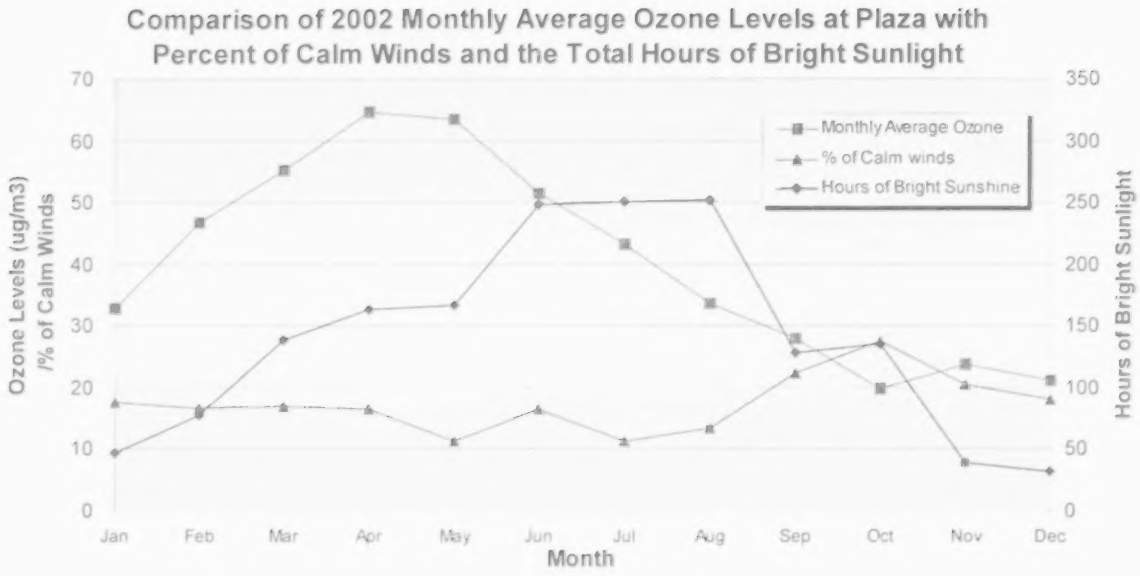
level for ozone (see Altshuller, et. al., and Browell, et. al.). There was at least one exceedance of the Level B daily objective recorded in each month in 2002 except for October and December. Monthly averages in March, April, May and June were higher than the Level B daily objective. No exceedances of the one-hour Level B objective were recorded in 2002.

Table 4.4.1
2002 Monthly Summary of O_3 Data at Plaza

	Monthly Average	No. of 1-Hour Values		Maximum Hourly Average	No. Of Daily Values		Maximum 24 Hour Average
	($\mu g/m^3$)	>100$\mu g/m^3$	>160$\mu g/m^3$	($\mu g/m^3$)	>30$\mu g/m^3$	>50$\mu g/m^3$	($\mu g/m^3$)
January	32.9	0	0	88	15	6	74.1
February	46.8	0	0	96	22	12	83.3
March	55.2	0	0	96	27	18	92.5
April	64.7	46	0	112	30	24	102.2
May	63.5	49	0	128	31	26	100.2
June	51.5	25	0	128	28	17	76.6
July	43.2	9	0	118	28	9	83.3
August	33.6	1	0	102	20	1	58.1
September	27.9	0	0	94	10	2	67.6
October	19.8	0	0	76	9	0	52.5
November	23.8	0	0	84	10	3	73.1
December	21.2	0	0	100	10	0	58.9
Annual	**40.3**	**130**	**0**	**128**	**240**	**118**	**102.2**

Figure 4.4.2 compares the monthly average ozone levels with the frequency of calm winds (<1 m/s) and the total hours of bright sunlight. Monthly average ozone over an extended period can be correlated with several meteorological factors. To get a better understanding of the ozone trend, all meteorological factors need to be examined, and annual average ozone levels should not be used solely as an indication of the trend in actual ozone concentrations in the troposphere. Since bright sunlight plays an important role in the production of ozone, more hours of bright sunlight can produce higher ozone levels. Calm winds can contribute to higher ozone levels in bright sunlight, but lower levels with lower radiation levels. Thus calm winds can contribute to either an increase or decrease in concentrations, depending on the time of day and the availability of precursor pollutants in the airshed. In most cases, calm winds occur at night when there is no solar radiation to help produce ozone.

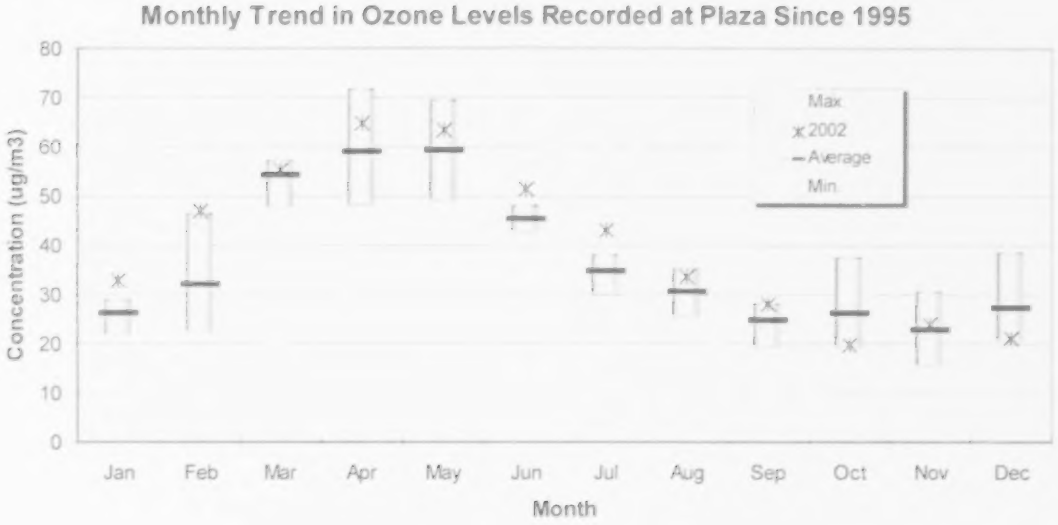
Figure 4.4.2



As shown in Figure 4.4.2, ozone levels increased sharply in late winter as the number of hours of bright sunshine increased. The month with the highest average ozone level (April) did not have the most sunlight. Ozone levels steadily decreased from May to October as the frequency of calm winds gradually increased, even though the hours of sunlight were high in June to August. Other meteorological factors that also play a role in the production/destruction of ozone were not included in this figure. For instance, lower ozone levels are associated with periods of rain whereas higher ozone levels can be associated with snow cover on a bright sunny day. Total precipitation amounts in 2002 were below the normal expected for each of the summer months (Fig. 3.14) which would indicate higher monthly ozone levels expected during those months. The frequency of wind direction may also play an important role. A higher frequency of winds blowing from concentrated NO_2 sources may result in lower ozone levels during the winter and higher levels during the summer. Solar radiation, which is usually the highest in May-July, contributes to higher hourly ozone peaks during these periods. In most cases, the interaction of all these meteorological parameters determines ozone levels.

Figure 4.4.3 shows the range in monthly average ozone levels at the downtown location since monitoring began at that site in 1995. Monthly average ozone levels in 2002 were above normal during ten months and below normal for the other two months (Oct. and Dec.). Levels in January, February, June and July were the highest ever recorded for those months.

Figure 4.4.3



This figure also shows the typical annual pattern. Monthly averages tend to be the highest in spring, and lowest in late autumn. However, extremely high hourly averages can occur in the summer. Monthly averages for June have varied from only 9 $\mu g/m^3$, whereas in February the averages varied as much as 25 $\mu g/m^3$.

Figures 4.4.4 shows the O_3 pollution rose for the Plaza site based on the 2002 meteorological data. Wind directions were only considered whenever wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed and at night these pollutants may react with ozone causing low ozone levels no matter what direction the wind is blowing from). Unlike the TRS and SO_2 pollution roses, low levels occurred quite often (40% of the time) when winds were blowing from the east. This was probably due to ozone being scavenged out of the atmosphere by NO and other pollutants from the industrial sources northeast of the monitoring site. The highest ozone levels (> 100 $\mu g/m^3$) occurred with winds blowing from almost every sector. Unlike other pollutants, the average concentration during light winds tends to be low (< 10 $\mu g/m^3$ in 2002). This is due to a combination of other pollutants in the airshed (light winds tend to be associated with a build-up of certain pollutants) causing reduce ozone during the absence of sunlight, and due to ozone being removed from the airshed by dry deposition. Although pollutants such as NO_2 and volatile organics can contribute to the production of ozone in the presence of sunlight, NO can destroy it. Close to the source the reaction tends to be dominated by the destruction, whereas further downwind from the NO sources, ozone could be higher than downtown. It is noticeable that low ozone levels rarely occurred (less than 5% of the time) when winds were from the north or south. This was likely due to the low frequency of light winds from those sectors. The average wind speeds from the south and north sectors were the highest of all sixteen wind sectors. Average winds speeds ranged from 1.3 m/s from the southeast to 4.1 m/s from the south (average wind speed from the

north was 3.3 m/s and 3.2 from the northeast). Also the frequency of light winds (< 1 m/s) plays a major role in determining the frequency of low ozone levels. All sectors that had light winds greater than 19% of the time in 2002 also had ozone levels below 40 ug/m³ greater than 25% of the time. As previously mentioned, lights winds usually result in a build up of other pollutants in the airshed that reduce ozone.

Figure 4.4.3 O3 Pollution Rose Recorded at Plaza for 2002

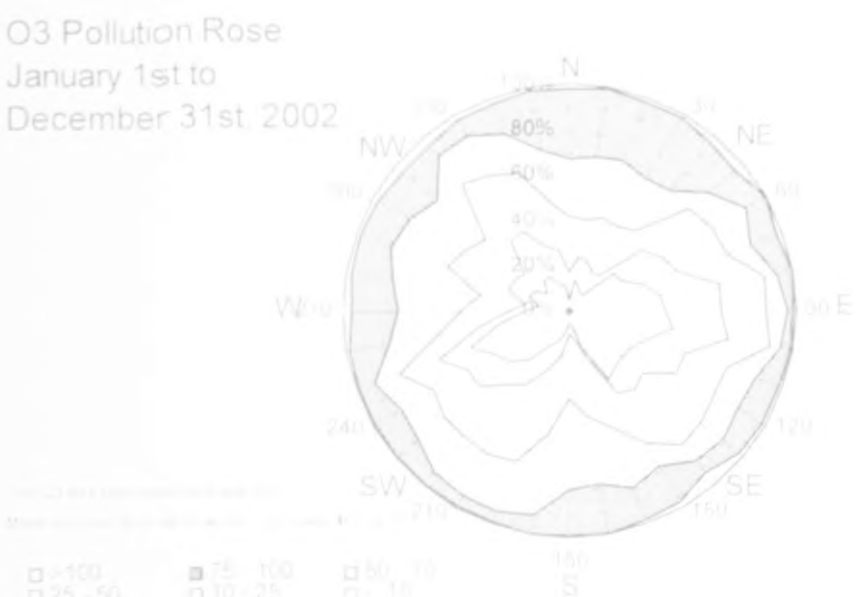


Figure 4.4.5 shows the typical diurnal pattern of ozone expected during each season for 2002, as represented by selected indicator months. It is uncertain as to why the daily levels of spring (April) are much higher than any other season. Possible reasons could be an increase in ozone precursors in the atmosphere, more snow cover at higher elevations, an increase in stratospheric intrusion, or even a combination of all of these factors. Average hourly ozone levels ranged from about 47 ug/m³ to 88 ug/m³ in April. Lower levels during the night were likely due to ozone being scavenged out and none being generated in the absence of sunlight. Daytime maximum levels in July and February were similar. However night-time levels were about 10 ug/m³ higher in February than in July. The diurnal trend in the winter (December) only shows a slight increase in the day-time, which is expected considering the short period of bright sunshine and the weak solar radiation in that month. Night-time levels were higher than those for September. This was due to better mixing at night in December than in September. Monthly average wind speeds in December were only 0.15 m/s stronger than in September, but night-time winds were about 0.5 m/s less than in September.

Figure 4.4.5

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Figure 4.4.4: O_3 Pollution Rose Recorded at Plaza for 2002

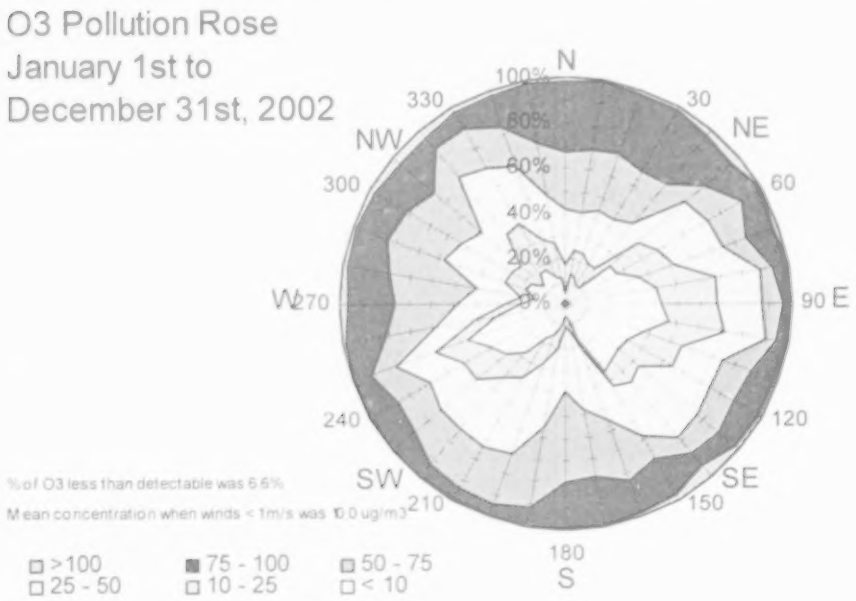

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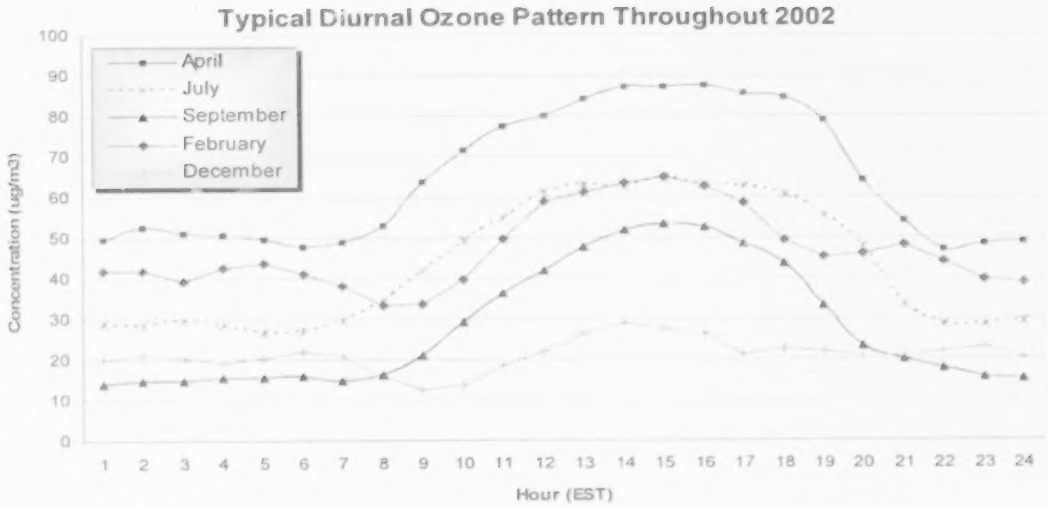
Figure 4.4.5



4.4.1 O_3 Annual Trend

Table 4.4.2 and Figure 4.4.6 summarize the O_3 data collected at Plaza. With seven complete years of data, ozone levels have increased slightly from 1996 to 2002 (maximum of about 16%). No ozone exceedances of the Level B one-hour objective occurred in 2002. The maximum one-hour and eight-hour averages (128 µg/m^3 and 115 µg/m^3 recorded in May), the number of exceedances of the one-hour Level A objective was the lowest recorded since 1997. The number of exceedances of the Level A and B 24-hour objectives were the highest ever recorded at that site since monitoring started in 1995. As mentioned earlier in this section, the longer the averaging period the more meteorological factors there are to influence the ozone levels.

Table 4.4.2 compares the maximum rolling 24-hour averages to the maximum daily (midnight to midnight) averages. To assess health effects, the rolling average needs to be considered. The maximum daily average can be considerably lower than the maximum 24-hour rolling average and as shown in this table the maximum daily average can range from 85% of the 24-hour rolling average as in 1998 to 98% as in 1997. This could be due to high ozone levels that occur at night. Daily averages could separate these levels into two days (levels prior to midnight will be included in the daily average for that day whereas levels occurring just after midnight are included in the daily average for the next day) but rolling 24-hour averages would include all these high night-time levels.

In July 1999, the federal government released the "National Ambient Air Quality Objectives for Ground-Level Ozone". Which established a Canada Wide Standard for ozone that takes effect in 2010. The Canada-Wide Standard for ozone is 130 µg/m^3, which is the annual 4th highest 8-hour value, averaged over three consecutive years. So far in Prince George, the Canada-Wide Standard has been achieved. Only three times in the last three years have single 8-hour averages exceeded 130 µg/m^3, and those exceedances occurred on two days in August, 2001.

Table 4.4.2

Annual Trend Summary of O_3 Data at Plaza

Year	Annual Avg. ($\mu g/m^3$)	No. (%) of 1-Hour Values >100$\mu g/m^3$	>160$\mu g/m^3$	Max. Hourly Avg. ($\mu g/m^3$)	No. of 8-Hr. Values >130$\mu g/m^3$	Max. 8-Hr. Avg. ($\mu g/m^3$)	No. (%) of Daily Values >30$\mu g/m^3$	>50$\mu g/m^3$	Max. Daily Avg. ($\mu g/m^3$)	Max. 24-Hr. Avg. ($\mu g/m^3$)	No. of Hours Instr. Operated
1995	-	30 (0.5%)	0	112	0	104	109 (45.2%)	32 (13.3%)	75.2	76.7	5,548*
1996	35.2	21 (0.3%)	0	120	0	109	209 (58.2%)	87 (24.2%)	88.1	91.1	8,290
1997	35.3	57 (0.7%)	0	120	0	107	217 (59.6%)	87 (23.9%)	82.7	84.1	8,358
1998	37.3	166 (2.0%)	0	156	2	132	217 (60.3%)	93 (25.8%)	85.0	99.9	8,284
1999	38.2	153 (1.9%)	0	140	0	117	223 (61.9%)	94 (26.1%)	103.3	105.4	8,265
2000	36.4	182 (2.2%)	0	132	0	115	200 (55.1%)	89 (24.5%)	96.2	107.2	8,309
2001	40.7	172 (2.0%)	2	170	3	137	238 (65.2%)	117 (32.1%)	90.0	99.5	8,319
2002	40.3	130 (1.5%)	0	128	0	115	240 (66.1%)	118 (32.5%)	98.7	102.2	8,591

* Note: API Analyzer installed in late April 1995

Figure 4.4.6

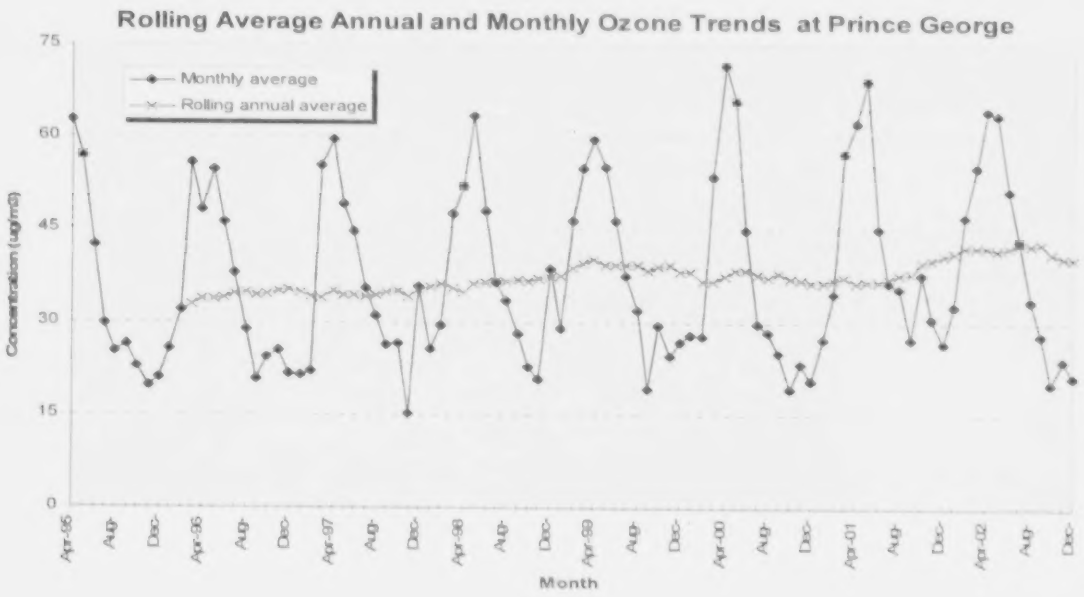


Figure 4.4.6 also shows that monthly averages tend to be the lowest during autumn and early winter, and the highest during spring. Monthly averages during the spring of 2000-2002 were the three highest recorded at this site. Rolling annual averages have been gradually increasing since 1995.

Table 4.4.3 shows the annual percentiles of both the 1-hour and 8-hour ozone averages for the past six years. The percentiles give a more complete indication of trends than just annual averages, maximum values, or the number of objective exceedances, they also give a better understanding as to the reasons for any trends. The higher percentiles for both the 1-hour and 8-hour increased in 1998 and have been stable since. Percentiles below the 75th show hardly any change until 2001. There was a noticeable increase for both the one-hour and eight-hour ozone concentrations in 2001 and 2002 for the 25th, 50th and 75th percentile. The reasons for this increased frequency of higher levels might include an increase in ozone precursors or in solar intensity, or possibly the result of the monitor reading slightly higher in 2001 and 2002. There are small, consistent increases in the higher percentiles similar to the slight increase in annual averages even though the number of sunlight hours has decreased since 1998.

Table 4.4.3
Percentiles of 1-hour and 8-hour Ozone Levels Recorded at Plaza

Year	Percentile ($\mu g/m^3$)									Max.	No. of
	5	10	25	50	75	90	95	98	99	($\mu g/m^3$)	Samples
1-hour											
1996	0	2	10	34	56	74	82	88	94	120	8635
1997	1	2	8	34	58	74	82	90	96	120	8660
1998	2	4	12	32	60	78	88	100	110	156	8584
1999	2	2	10	36	58	82	91	100	104	140	8617
2000	2	2	10	32	56	82	92	102	106	132	8650
2001	2	2	12	40	64	82	92	101	106	170	8566
2002	0	2	12	38	64	82	90	100	104	128	8591
8-hour											
1996	2	5	15	34	54	69	77	85	89	109	8644
1997	2	4	14	34	53	69	77	85	90	107	8646
1998	4	6	16	34	55	72	82	93	102	132	8598
1999	3	5	17	36	56	76	86	95	101	117	8569
2000	3	6	14	32	54	76	88	97	101	115	8620
2001	3	6	18	39	60	77	86	95	100	137	8602
2002	2	4	18	38	60	79	87	95	100	115	8644

4.4.2 Comparison of O_3 Levels with Other B.C. Locations

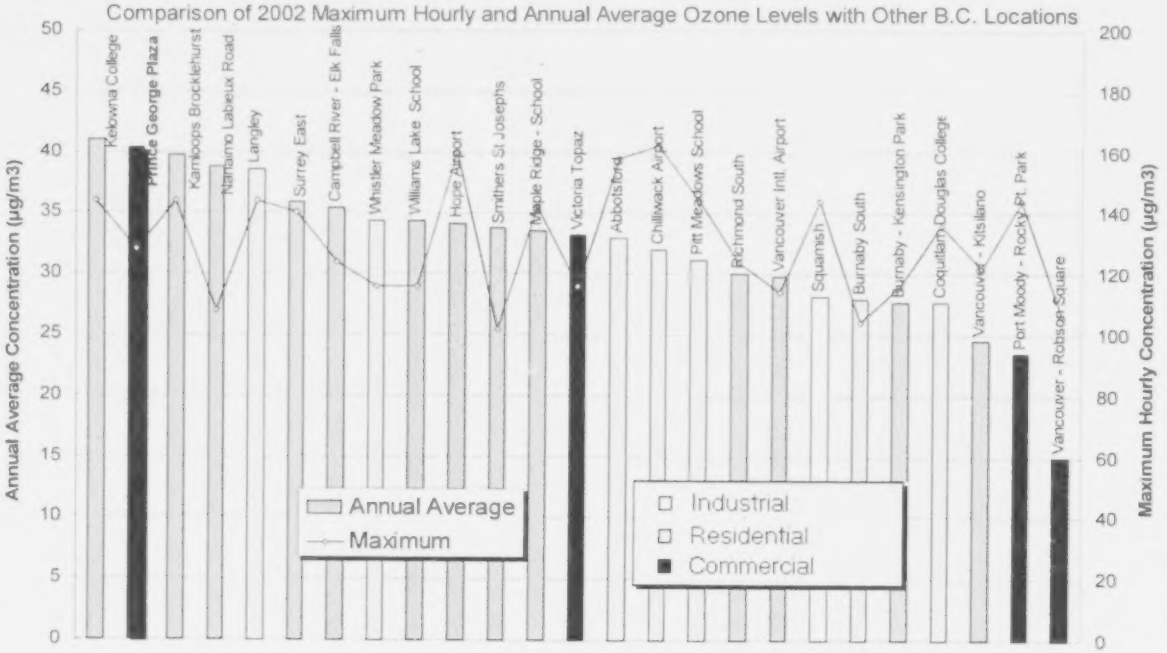
Figure 4.4.7 compares the 2002 ozone annual average at the Plaza site with other monitoring sites in B.C. (only sites with greater than 75% of data captured).

In 2002, there were 25 ozone monitoring sites in B.C. but only eight outside the Greater Vancouver Regional District. Four of these nine sites were the four highest O_3 annual averages recorded in 2002. The lowest annual averages were for sites that recorded the highest annual averages for NO_2, which is expected since NO reacts with ozone, producing NO_2 and causing O_3 concentrations to drop to near zero. Sites in the Greater Vancouver Regional District tend to have lower annual O_3 averages than other sites, but higher hourly summertime peaks.

The two sites that recorded the highest annual averages in 2001 are no longer monitoring ozone. Kelowna recorded the highest annual average. The Plaza site recorded the second highest annual average.

Out of the 23 sites that monitored ozone in 2001 and 2002, ten sites recorded lower levels in 2002. Most of the sites located in interior B.C. recorded lower levels in 2002. Only Chilliwack recorded exceedances of the Level B one-hour objective in 2002. Only eight sites reported higher maximum hourly levels in 2002 than in 2001. Williams Lake showed the biggest decrease and Nanaimo showed the biggest increase in levels in 2002.

Figure 4.4.7



Because of the complexity in the production of ozone, annual average concentrations for ozone may not be an indication of whether a site has ozone concerns. As shown in Figure 4.4.7, the sites with the highest annual averages did not record the highest maximum hourly concentrations. Chilliwack, which recorded the 15th highest annual average, had the highest maximum hourly concentration. Plaza, which had the second highest annual average, placed 14th for the maximum one-hour average.

4.5 Particulate Matter (PM_{10}) Results

Particulate matter refers to small particles ranging in size from 0.001 μm to 100 μm. Particles less than 10 μm tend to stay suspended longer in the atmosphere. The inability of the atmosphere to disperse small particulates is often evident during hazy days in the autumn when mixing is weak.

Larger particles may cause a nuisance or irritation, but smaller particles (less than 10 μm) cause the greatest health effects because they can be inhaled deep into the lung cavities. Recent health and medical studies show that this type of particulate matter (alone, or combined with other pollutants in the air) causes serious health impacts (see Vedal, 1995). These health effects include premature death, increased hospital admissions, increased respiratory symptoms and disease, and decreased lung function. The main effects on vegetation are reduced growth and productivity due to interference with photosynthesis and phototoxic impacts as a result of particulate composition.

Particles in this size range, known as PM_{10}, come from man-made sources such as internal combustion engines, industrial processes, commercial and residential burning, and natural sources such as wind blown soil, volcanic dust, sea spray, pollen and forest fires. Particles can be classified as primary or secondary based on their origins. Primary particles are those that do not change their form significantly after being emitted from a source. Secondary particles are formed after gases released from a source are transformed by chemical reactions with other pollutants in the atmosphere, or by condensation of emitted gases. Secondary particles may be generated from natural sources (volcanoes, decomposition of biological matter, trees) or man-made sources (industrial, motor vehicles). Gases can be transformed in the atmosphere as chemical reactions take place to form particles, such as sulphates, nitrates and various hydrocarbon species. The generation of these particles can result in acidic precipitation and reduction of visibility, components typical of smog conditions. The chemical and physical compositions of PM_{10} vary depending on location, time of year, and meteorology.

In Prince George the major PM_{10} emission sources are pulp mills, sawmills and road dust (see Prince George Airshed Technical Management Committee, 1996).

PM_{10} is measured by drawing air through a size selective inlet prior to collection on a teflon coated glass fibre filter at a rate of about 1.14 cubic metres per minute (Figure 4.5.1). These non-continuous samplers are run for 24 consecutive hours on a 6 day cycle (i.e., once every sixth day) and the results are not available for several months due to the processing and analysis of the filters. The minimum detection limit using this method is 2 $\mu g/m^3$.

Figure 4.5.1: PM_{10} Non-Continuous Monitor

Figure 4.5.2: PM_{10} TEOM Monitor

Particulate is also measured continuously using the Tapered Element Oscillating Microbalance (TEOM) technology (Figure 4.5.2). This technique involves the measurement of mass collected on a filter seated on the tapered element and monitoring the changes in oscillating frequency of the tapered element as loading of the filter occurs. This method not only gives instantaneous 24-hour average concentrations but also provides measurements on a continuous basis. The minimum detection limit of the TEOM monitor is 5 $\mu g/m^3$.

In 2002, there were four non-continuous and three continuous monitoring sites in Prince George. A continuous monitor located at Glenview in the Hart Highlands ceased operation in February, 2001. Data for that site is provided in Appendix E. The quality of the non-continuous PM_{10} data is assessed by regular measurement of laboratory filter weighing error and by calibration of the airmass flow controllers on the samplers. Continuous data quality is evaluated by bi-weekly field checks and quarterly mass calibrations. Data completeness was satisfactory with valid data ranging from 97.0% to 99.7% at the Plaza, BCR, and Gladstone continuous monitors, respectively.

Table 4.5.1
2002 Airshed PM_{10} Summary

Station	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values			Maximum Daily ($\mu g/m^3$)	Minimum Daily ($\mu g/m^3$)	No. of Values
		>50$\mu g/m^3$	>100$\mu g/m^3$	>150$\mu g/m^3$			
Non-							
Lakewood	13.2	0	0	0	45	2	61
Van Bien	20.4	3 (4.9%)	0	0	62	4	61
CNR	20.9	3 (5.1%)	0	0	73	4	59
Plaza	18.2	2 (3.3%)	0	0	62	3	61
Continuous							
Plaza	18.2	12 (3.4%)	0	0	75	3	353
BCR- Warehouse	22.1	27 (7.4%)	0	0	87	4	365
Gladstone	13.6	4 (1.1%)	0	0	68	3	365

Table 4.5.1 summarizes the continuous and non-continuous PM_{10} data from 2002 for all the monitoring sites in Prince George. The BCR site recorded the highest percent of exceedances of the Level B daily objective (50 $\mu g/m^3$). The relatively high annual average and objective exceedance rate at the BCR site suggests the effect of the local PM_{10} sources, which include unpaved railway and log storage yards and two sawmills in particular. Monitoring of $PM_{2.5}$ at the same location could indicate whether dust or combustion particles is the predominant component.

To evaluate how well data from the non-continuous monitors sampled every six days represented the full year, we compared the 365 days of data from the continuous monitors with data from the 61 days sampled based on the six-day NAPS schedule. Analysis of this data for 1994-2002 is provided in Table 4.5.2. For 2002, all three sites showed average levels about 0.3 – 0.9 $\mu g/m^3$ higher for the sixth day database compared to the continuous database. The frequency of exceedances of the Level B objective at Plaza was similar for the six-day sampling compared to monitoring continuously, but much lower at the BCR and Gladstone sites. Thus the non-continuous monitors may have overestimated annual PM_{10} levels relative to the continuous monitors in 2002, but under-estimated annual levels in other years (e.g., 2001).

Table 4.5.2
Comparison of the Six-day (NAPS) with the Full Year Data

Site	Average Concentration						Frequency of Exceedances					
	Plaza ($\mu g/m^3$)		BCR ($\mu g/m^3$)		Gladstone ($\mu g/m^3$)		Plaza		BCR		Gladstone	
	Cont.	Sixth-day	Cont.	Sixth-day	Cont.	Sixth-day	Cont.	Sixth-day	Cont.	Sixth-day	Cont.	Sixth-day
1994	22.3	21.1	-	-	-	-	5.6%	5.4%	-	-	-	-
1995	24.2	21.5	-	-	-	-	9.1%	4.9%	-	-	-	-
1996	20.5	19.3	15.0	14.9	-	-	2.8%	1.7%	5.3%	-	1.9%	0%
1997	20.2	20.4	14.8	14.8	24.2	23.6	3.6%	1.6%	8.8%	6.7%	1.9%	0%
1998	22.7	24.1	17.2	18.4	29.1	29.7	5.5%	6.6%	13.5%	13.3%	1.9%	0%
1999	17.8	18.4	12.7	13.0	21.3	22.8	2.8%	1.7%	5.5%	6.8%	0%	0%
2000	18.0	18.4	13.7	13.3	20.0	20.0	2.5%	1.6%	3.6%	4.9%	1.1%	1.6%
2001	18.2	17.1	13.5	13.3	20.1	19.1	2.6%	3.3%	4.7%	1.6%	0.6%	0%
2002	18.2	18.9	13.6	13.9	22.1	23.0	3.4%	3.3%	7.4%	4.9%	1.1%	0%

Annual averages for the non-continuous monitors may not be as representative as the continuous monitors. At Plaza using the non-continuous data it appears that average levels increased by 10% over the past year, but data from the continuous monitor shows no increase. This is due to annual averages for monitoring every sixth day in 2001 being 1.1 $\mu g/m^3$ lower than the continuous monitoring data but 0.7 $\mu g/m^3$ higher in 2002. Since 1994, at Plaza the differences in concentrations from every sixth day to continuous ranged from 2.7 $\mu g/m^3$ in 1995 to -1.5 $\mu g/m^3$ in 1998. This helps explain why annual average at Plaza recorded with the non-continuous monitors are sometimes much higher or lower than that recorded with the continuous monitor. The lower sampling frequency produced more variable annual levels, especially in the

Prince George airshed where episodes are relatively severe but infrequent, so that days mixed in the sampling rotation can have a significant effect on the annual average.

4.5.1 PM_{10} Continuous Monitoring Results

In 2002, PM_{10} was continuously sampled at the Plaza, Gladstone, and BCR stations. Monitoring for PM_{10} at Glenview ceased in February, 2001. Tables 4.5.3 to Table 4.5.5 provide the monthly summaries of the data from these monitors.

Maximum monthly average PM_{10} levels have historically occurred in March due to an increase in dust from accumulated winter road sand that has been crushed and dispersed by motor vehicles. This was not the case in 2002 at any of the sites. October and November produced the highest PM_{10} levels at most of the monitoring sites. The lowest monthly average PM_{10} levels occurred in September at Plaza and Gladstone and in February at the BCR site. There were five months in which there were no 24-hour Level B exceedances at any site in 2002. Even though crustal material including road dust is be expected to be more prevalent during late winter than late autumn. This data indicates the significance of the non-dust sources, particularly as affected by the poorer mixing conditions in the winter and fall.

It should be noted that these monitoring sites are elevated and levels at ground level are likely higher near roadways. A short term monitoring program was conducted from March to May 1996 to determine the effect of road dust on PM_{10} levels at street level. A site located on a one story building at the same intersection as the Plaza site measured 24-hour levels that were on average 7 $\mu g/m^3$ (30%) higher than what was recorded at Plaza. During one occasion, levels at this site were 69% higher than at Plaza (16 ug/m3 at Plaza and 27 ug/m3 at the one story building). Since then, with the improvements made in reducing road dust, it is expected that the concentrations at the different elevations are now less than what was shown in 1996.

Table 4.5.3
2002 Monthly Summary of Continuous PM_{10} Data at Plaza

	Monthly Average ($\mu g/m^3$)	Maximum Hourly ($\mu g/m^3$)	No. of Daily Values >50$\mu g/m^3$	No. of Daily Values >100$\mu g/m^3$	Maximum 24 Hour ($\mu g/m^3$)	Minimum 24 Hour ($\mu g/m^3$)
January	12.6	90	0	0	31.1	3.2
February	13.6	154	0	0	45.5	3.5
March	15.4	76	0	0	39.9	3.3
April	20.0	153	1	0	52.6	3.2
May	16.3	90	0	0	38.7	5.2
June	21.5	104	0	0	51.3	2.4
July	15.5	100	0	0	34.9	2.7
August	17.9	95	0	0	43.0	5.5
September	12.1	76	0	0	25.5	2.8
October	24.6	120	3	0	76.1	4.7
November	29.1	149	8	0	81.1	5.7
December	19.8	85	0	0	51.3	6.0
Annual	**18.2**	**154**	**12**	**0**	**81.1**	**2.4**

Table 4.5.4
2002 Monthly Summary of Continuous PM_{10} Data at Gladstone

	Monthly Average ($\mu g/m^3$)	Maximum Hourly ($\mu g/m^3$)	No. of Daily Values >50$\mu g/m^3$	No. of Daily Values >100$\mu g/m^3$	Maximum 24 Hour ($\mu g/m^3$)	Minimum 24 Hour ($\mu g/m^3$)
January	10.8	49	0	0	29.4	2.2
February	9.8	52	0	0	25.6	2.4
March	11.7	55	0	0	29.7	2.3
April	13.7	85	0	0	30.0	3.8
May	11.1	73	0	0	23.7	3.0
June	13.4	67	0	0	33.0	2.6
July	11.0	62	0	0	25.3	3.3
August	12.3	70	0	0	33.3	5.7
September	9.5	55	0	0	23.3	2.5
October	16.6	109	1	0	66.9	4.4
November	23.8	100	3	0	74.2	2.8
December	18.8	77	0	0	50.4	2.8
Annual	**13.6**	**109**	**4**	**0**	**74.2**	**2.2**

Table 4.5.5
2002 Monthly Summary of Continuous PM_{10} Data at BCR

	Monthly Average ($\mu g/m^3$)	Maximum Hourly ($\mu g/m^3$)	No. of Daily Values >50$\mu g/m^3$	No. of Daily Values >100$\mu g/m^3$	Maximum 24 Hour ($\mu g/m^3$)	Minimum 24 Hour ($\mu g/m^3$)
January	15.1	77	0	0	33.4	3.5
February	11.9	49	0	0	30.6	4.1
March	16.2	72	0	0	36.4	3.4
April	23.7	260	3	0	62.2	3.9
May	19.7	239	2	0	79.2	2.5
June	29.2	430	5	0	88.5	2.0
July	19.3	141	0	0	47.4	4.2
August	26.4	244	3	0	65.7	4.8
September	15.8	107	0	0	38.1	3.3
October	28.4	127	4	0	79.4	6.7
November	32.2	170	7	0	82.3	5.4
December	26.8	239	3	0	57.1	5.0
Annual	**22.1**	**430**	**27**	**0**	**88.5**	**2.0**

Figure 4.5.3

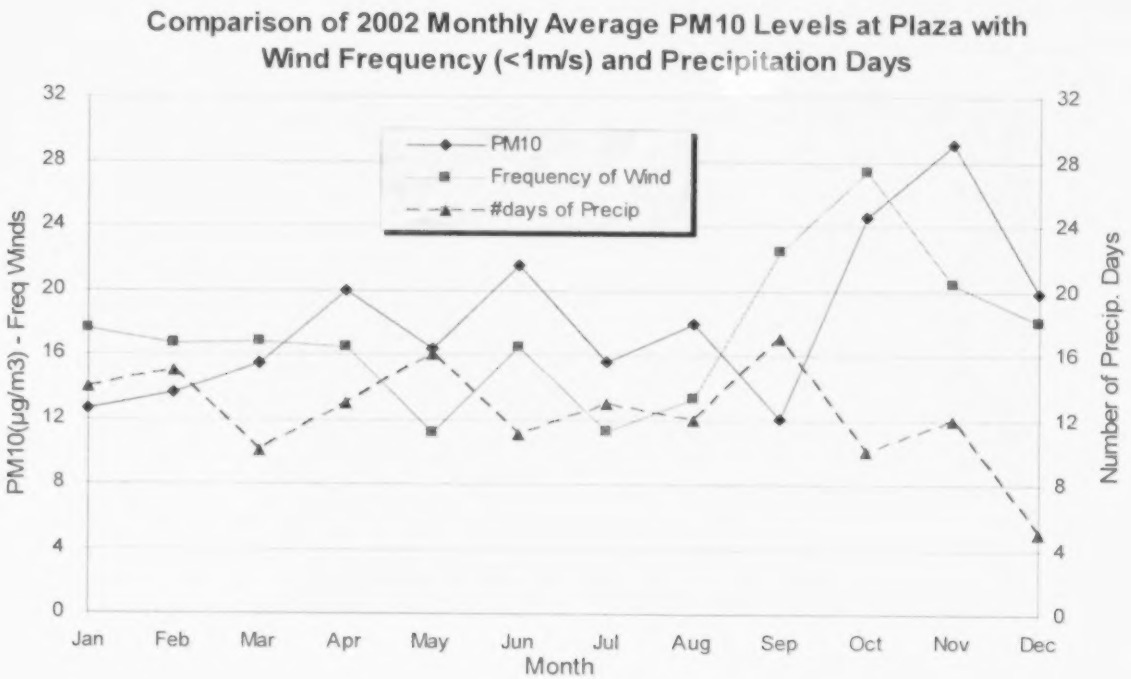


Figure 4.5.3 shows the relationships between average monthly PM_{10} levels, frequency of wind speeds less than 1 m/s, and the number of precipitation days. There is a good correlation between PM_{10} concentration and the percent of calm winds in 2002. Three of the four months with the highest PM_{10} averages also had the highest frequency of calm winds. The September average was the lowest even though there was a higher frequency of calm winds. The low average could be due to the highest number of days with precipitation in that month. Monthly average PM_{10} concentrations generally have been shown to increase in those months with the lowest number of days of precipitation. However, this may not always be the case. A variation in local emissions throughout the year may make it difficult to determine a correlation (i.e., increase open burning during the late autumn). Sometimes a combination of emissions, the number of precipitation days and the frequency of calms may have to be considered.

Figure 4.5.4 shows the range in monthly averages recorded at Plaza since 1995. Monthly averages ranged from a high of 44.2 $\mu g/m^3$ (March 1995) to a low of 12.1 $\mu g/m^3$ (September 2002). Monthly averages at Plaza have tended to be the highest in March due primarily to road dust from winter sand and the lowest during December. March 2002 was substantially below normal likely due to improved spring road dust management and perhaps meteorology as well. Monthly averages in 2002 were above normal for only four months (June, October, November and December) and all four months recorded levels that were the highest ever recorded for those months. 2002 levels during January, February, March, and September were the lowest ever recorded for those months (since 1995). The monthly average recorded in September was the lowest ever recorded. The higher than average October and November averages were due to advisory episodes in each of those months in 2002.

Figure 4.5.4

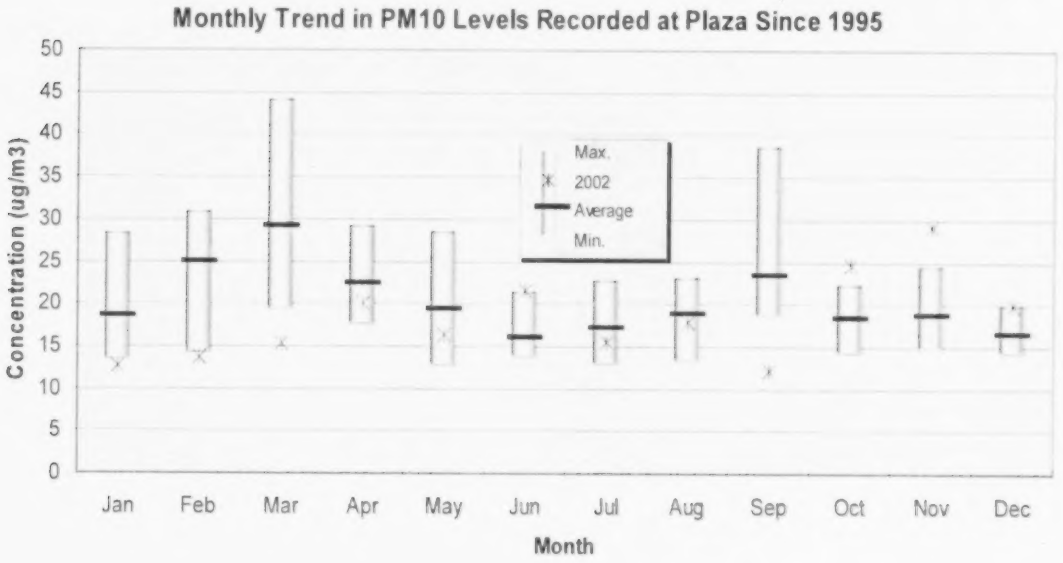


Figure 4.5.5 shows the range in monthly averages recorded at Gladstone since monitoring began at that site in 1996. Monthly averages ranged from a high of 24.2 µg/m^3 (Feb. 1996) to a low of 9.0 µg/m^3 (May 1999). Monthly averages have tended to be the highest during February-March and the lowest during June. This pattern is similar to that at Plaza except at Plaza the monthly average in March is higher than that in February. This is probably due to Gladstone being located in a residential area and is affected more from residential heating during the winter conditions, and the Plaza site being located in the downtown location is affect more by the springtime road dust. The highest monthly average ever recorded in June was lower than the overall monthly average recorded during all other months, except for May and July. Monthly averages in 2002 were above normal for four months (June, October, November and December) and the last two months recorded the highest levels ever recorded for those months. The levels in 2002 during the months of February, March and September were the lowest average levels ever recorded for those months since monitoring began at that site.

Figure 4.5.5

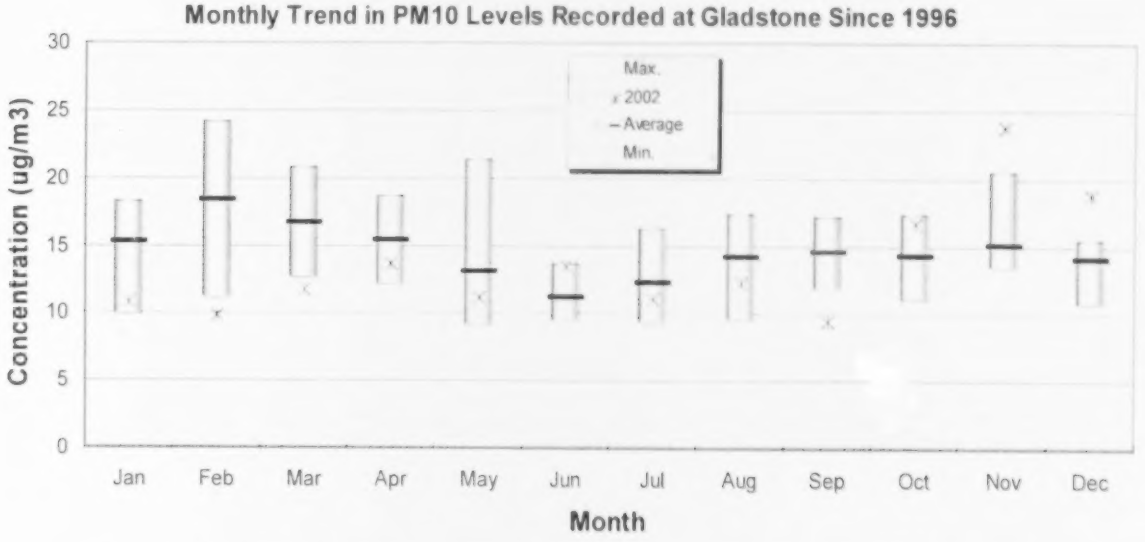


Figure 4.5.6 shows the range in monthly averages recorded at the BCR site. Monthly averages ranged from a high of 49.1 µg/m^3 (April 1998) to a low of 11.9 µg/m^3 (February 2002). Unlike the other two sites, monthly averages at BCR tend to be the highest during April rather than late winter and early spring at Plaza and Gladstone. There is another smaller peak in levels during late summer. Monthly averages in 2002 were above normal for five months (June, August, October, November, and December) and four of those five months recorded the highest monthly average ever recorded at that site for those months. There were four months in 2002 (January, February, March, and September) in which monthly averages were the lowest average levels ever recorded for those months since monitoring began at that site. The monthly average in February was the lowest monthly average ever recorded at that site. The monthly trend reflects the decreasing annual trend at this site due to, at least partially to, the elimination of wood residue burning at the BCR sawmills.

Figure 4.5.6

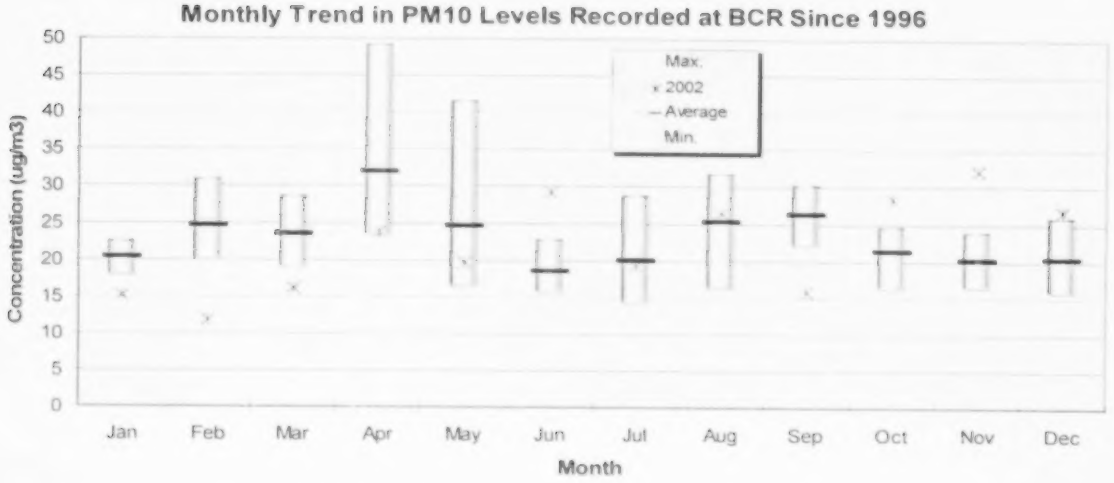


Figure 4.5.7 PM_{10} Pollution Rose Recorded at Plaza for 2002

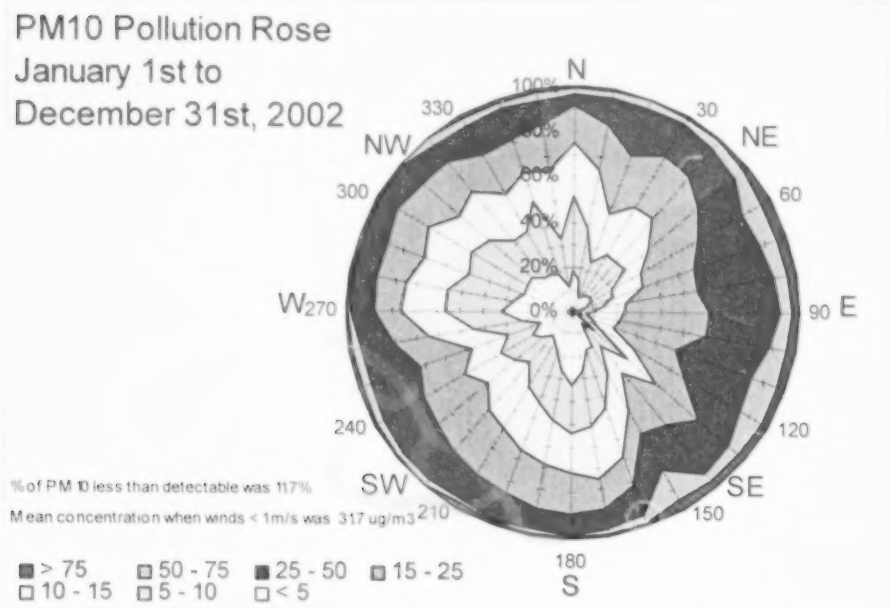


Figure 4.5.7 shows the 2002 PM_{10} pollution rose for the Plaza site based on the meteorological data from that site. Wind directions were only considered when wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). Maximum concentrations (> 50 $\mu g/m^3$) occurred mainly when winds were blowing from the east-northeast to southeast sector. One-hour average particulate levels were seldom below 10 $\mu g/m^3$ when winds were blowing from that direction. The average concentration when winds were less than 1 m/s was about 32 $\mu g/m^3$ (the 24-hour Level B objective is 50 $\mu g/m^3$).

4.5.2 PM_{10} Annual Trends

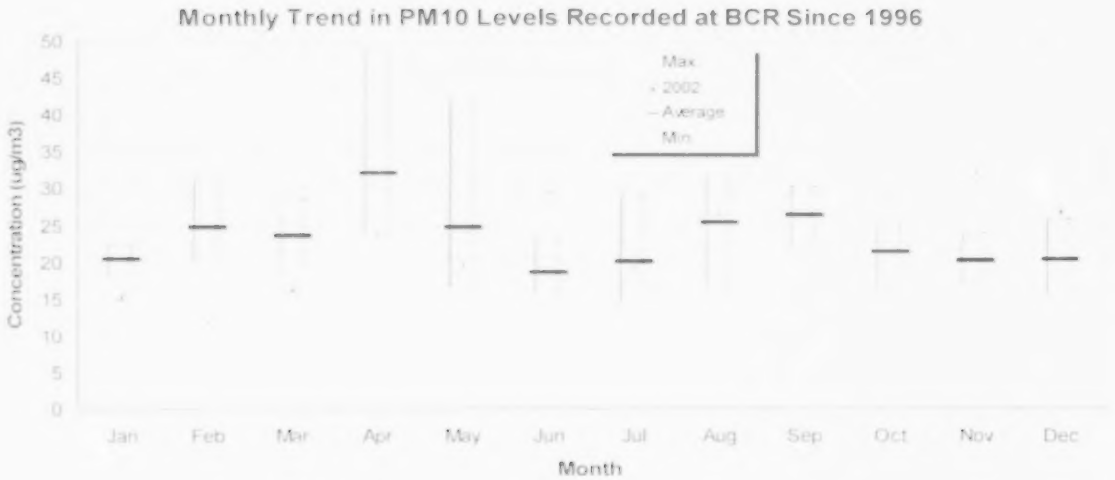


Figure 4.5.7 PM_{10} Pollution Rose Recorded at Plaza for 2002

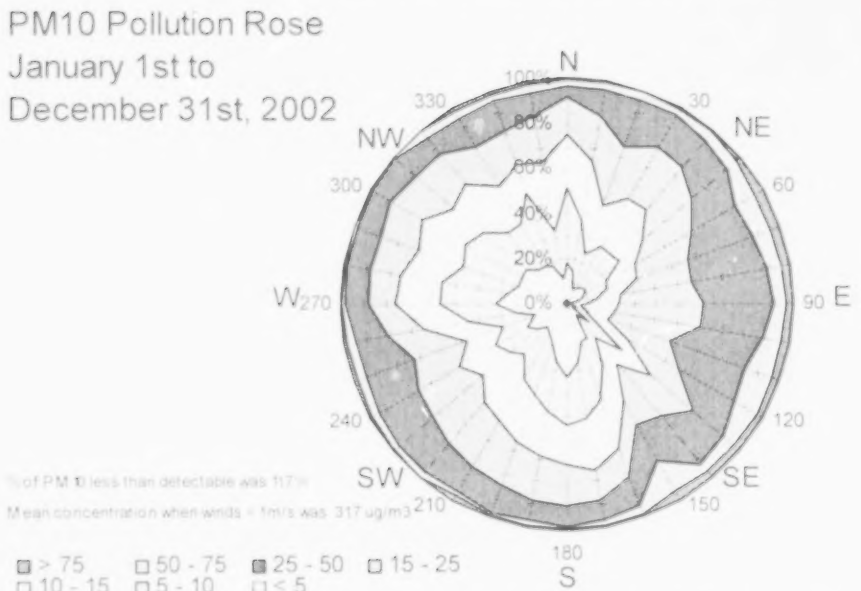


Figure 4.5.7 shows the 2002 PM_{10} pollution rose for the Plaza site based on the meteorological data from that site. Wind directions were only considered when wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). Maximum concentrations (> 50 $\mu g/m^3$) occurred mainly when winds were blowing from the east-northeast to southeast sector. One-hour average particulate levels were seldom below 10 $\mu g/m^3$ when winds were blowing from that direction. The average concentration when winds were less than 1 m/s was about 32 $\mu g/m^3$ (the 24-hour Level B objective is 50 $\mu g/m^3$).

4.5.2 PM_{10} Annual Trends

Tables 4.5.6 to 4.5.12 show the trends in PM_{10} levels at all the monitoring sites. Average 2002 PM_{10} levels at the Lakewood non-continuous monitoring sites was the lowest ever recorded at that site. However, levels at the other three non-continuous monitoring sites were higher than those in 2001 but still considerably lower than those in 1999, and ranged from a 10.1% decrease at Van Bien to a 25.4% decrease at CNR. A comparison between the HiVol monitor and the TEOM showed that from 1994-2001 the average PM_{10} levels recorded from the HiVol was consistently higher than that from the TEOM. However, in 2001-2002 the PM_{10} levels recorded from the HiVol was lower than that from the TEOM. Because continuous PM_{10} monitoring was not started at Plaza until 1992, and because the TEOM has historically underestimated levels to a greater extent (except for 2001-2002), non-continuous monitoring has been continued to assess trends at that site.

Average 2002 continuous PM_{10} levels at Plaza and Gladstone were similar to those in 2001 (Tables 4.5.10 and 4.5.12, respectively), but the annual average at BCR was much higher than that in 2001. Although the overall trend is decreasing since early to mid 1990's at all sites (Figure 4.5.8) The maximum hourly value recorded at Plaza and College Heights were well below values from the previous years at that site. The maximum hourly level recorded at BCR (June 12th) was the highest recorded at that site since August 1998 (582 $\mu g/m^3$). Due to an instrument upgrade annual averages of PM_{10} from the Plaza TEOM may have been under-estimated in 1992 and 1993. In January 1998 the internal temperature for the TEOM monitors was changed from 50°C to 40°C. This reduction in temperature was done to minimize the PM_{10} loss due to the volatization of sulphate, nitrate and VOC compounds with the small particles. It is assumed that this adjustment would increase concentrations, but the amount of increase is unknown

The main reason why the non-continuous monitors showed increased annual averages in 2002, while most of the continuous monitors showed similar values to 2001, could be due to the schedule of lower frequency monitoring. Analysis showed that the six day non-continuous values were lower than those of the continuous database for 2002. In 2002 the continuous PM_{10} average on the NAP's days compared to the 365 day average was about 4% higher at Plaza but in 2001 the six-day average was 6% lower (Table 4.5.2). Therefore, since the annual average in 2002 for the continuous monitor was the same as that in 2001, then the non-continuous monitors should have shown an increase of about 10% in 2002. However, the increase in the non-continuous data at Plaza was about 16%. CNR and Van Bien showed a similar increase, whereas Lakewood showed a 5% decrease in 2002 from the previous level. No reason for the decrease at this site could be found.

Table 4.5.6
Annual Trend Summary of Non-Continuous PM_{10} Data at Van Bien

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1990	-	7 (26.9%)	0	62	26*
1991	27.6	8 (13.6%)	0	84	59
1992	27.0	7 (12.5%)	0	89	56
1993	27.9	6 (10.2%)	0	99	59
1994	21.8	3 (6.3%)	0	69	48
1995	25.2	6 (10.2%)	1 (1.7%)	106	59
1996	23.9	4 (7.3%)	0	67	55
1997	20.8	3 (5.3%)	0	74	57
1998	28.4	6 (10.9%)	0	91	55
1999	22.7	3 (5.2%)	0	56	58
2000	17.4	2 (3.5%)	0	84	57
2001	17.4	1 (1.7%)	0	61	60
2002	20.4	3 (4.9%)	0	62	61

* Note: TSP (total suspended particulates) sampler converted to PM_{10} monitor on August 1, 1990.

Table 4.5.7
Annual Trend Summary of Non-Continuous PM_{10} Data at Lakewood

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1990	-	0	0	40	24*
1991	21.8	5 (8.5%)	0	89	59
1992	24.8	7 (11.9%)	0	74	59
1993	27.3	4 (7.6%)	1 (1.9%)	129	53
1994	18.9	1 (1.7%)	0	56	58
1995	18.7	4 (7.4%)	0	63	54
1996	16.3	0	0	50	59
1997	15.9	1 (1.7%)	0	51	59
1998	19.8	1 (1.9%)	0	61	54
1999	17.4	1 (1.8%)	0	74	56
2000	14.1	0	0	50	60
2001	13.9	1 (1.7%)	0	52	58
2002	13.2	0	0	45	61

* Note: TSP (total suspended particulates) sampler converted to PM_{10} monitor on August 1, 1990.

Table 4.5.8
Annual Trend Summary of Non-Continuous PM_{10} Data at the CNR Site

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1991	-	5 (13.2%)	2 (5.3%)	124	38*
1992	28.3	6 (10.3%)	1 (1.7%)	103	58
1993	33.3	14 (23.0%)	1 (1.6%)	104	61
1994	25.2	8 (13.6%)	0	75	59
1995	27.5	8 (13.3%)	1 (1.7%)	110	60
1996	28.1	5 (8.3%)	1 (1.7%)	110	60
1997	22.8	2 (3.6%)	0	65	55
1998	34.0	8 (13.8%)	2 (3.4%)	124	58
1999	28.0	8 (13.6%)	1 (1.7%)	106	59
2000	20.7	3 (5.1%)	0	61	59
2001	18.0	3 (4.9%)	0	56	61
2002	20.9	3 (5.1%)	0	73	59

* Note:Monitoring started May 6, 1991.

Table 4.5.9
Annual Trend Summary of Non-Continuous PM_{10} Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1990	-	2 (7.7%)	0	90	26*
1991	29.4	7(11.7%)	1 (1.7%)	217	60
1992	28.6	6(10.2%)	0	92	59
1993	30.2	10(16.7%)	0	92	60
1994	24.1	6(10.0%)	0	85	61
1995	23.6	4 (6.6%)	0	85	61
1996	21.7	2 (3.5%)	0	61	61
1997	20.8	1 (1.7%)	0	56	61
1998	26.9	5 (8.2%)	1 (1.6%)	111	61
1999	21.3	2 (3.3%)	0	73	60
2000	18.4	1 (1.6%)	0	65	61
2001	15.7	2 (3.3%)	0	52	61
2002	18.2	2 (3.3%)	0	62	61

* Note: TSP (total suspended particulates) sampler converted to PM_{10} monitor on August 1, 1990.

Table 4.5.10
Annual Trend Summary of Continuous PM_{10} Data at Plaza

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 50 $\mu g/m^3$	No. (%) of Days > 100 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	Hours Instrument Operated
1992	21.6	488	18 (6.1%)	0	80	7,083
1993	22.3	171	11 (4.5%)	0	75	5,828
1994*	22.3	284	19 (5.6%)	4 (1.2%)	117	8,162
1995	24.2	291	33 (9.1%)	2 (0.6%)	108	8,686
1996	20.5	373	10 (2.8%)	3 (0.8%)	152	8,567
1997	20.2	208	13 (3.6%)	0	76	8,719
1998	22.7	319	20 (5.5%)	2 (0.5%)	114	8,719
1999	17.8	211	10 (2.8%)	0	98	8,609
2000	18.0	175	9 (2.5%)	0	71	8,695
2001	18.2	170	9 (2.6%)	1 (0.3%)	110	8,683
2002	18.2	154	12 (3.4%)	0	75	8,495

* Monitor returned in January after upgrades

Table 4.5.11
Annual Trend Summary of Continuous PM_{10} Data at the BCR-Warehouse

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 50 $\mu g/m^3$	No. (%) Of Days > 100 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	Hours Instrument Operated
1996	-	125	5 (5.3%)	0 (0 %)	68	2,263*
1997	24.2	401	32 (8.8%)	2 (0.5%)	111	8,705
1998	29.1	582	49 (13.5%)	4 (1.1%)	127	8,702
1999	21.3	380	20 (5.5%)	0 (0%)	79	8,718
2000	20.0	288	13 (3.6%)	0 (0%)	86	8,739
2001	20.1	387	17 (4.7%)	0 (0%)	98	8,634
2002	22.1	430	27 (7.4%)	0 (0%)	84	8,696

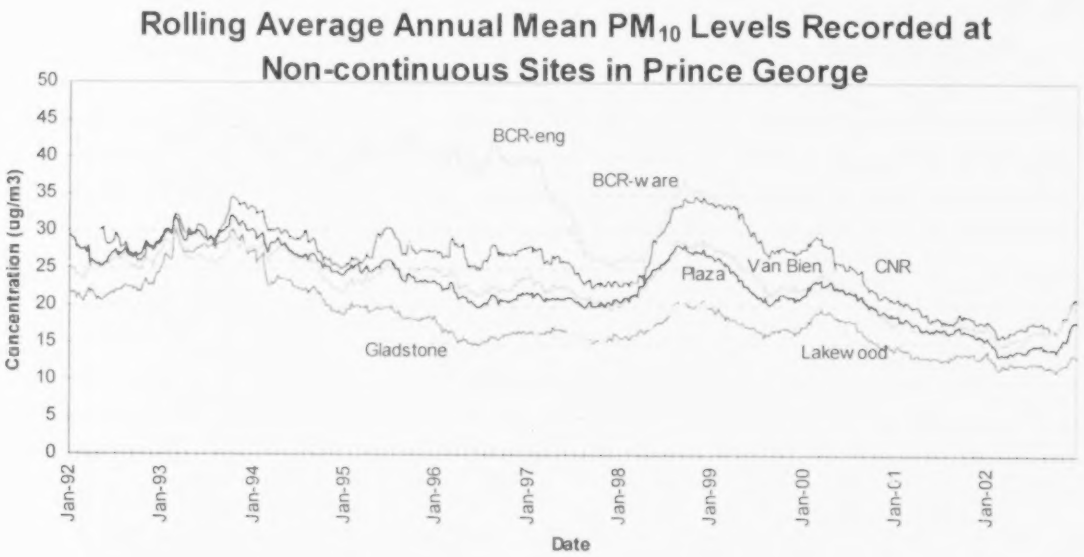
* Note: Monitoring started September 28, 1996.

Table 4.5.12
Annual Trend Summary of Continuous PM_{10} Data at Gladstone

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 50 $\mu g/m^3$	No. (%) of Days > 100 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	Hours Instrument Operated
1996	15.0	253	7 (1.9%)	1 (0.3%)	102	8,688
1997	14.8	155	7 (1.9%)	0 (0%)	71	8,673
1998	17.2	207	7 (1.9%)	0 (0%)	74	8,642
1999	12.7	127	0 (0%)	0 (0%)	47	8,663
2000	13.7	148	4 (1.1%)	0 (0%)	55	8,686
2001	13.5	164	2 (0.6%)	0 (0%)	78	8,696
2002	13.6	109	4 (1.1%)	0 (0%)	68	8,707

Figure 4.5.8 shows the trend in the annual mean PM_{10} levels recorded at non-continuous monitoring sites in Prince George. These means are calculated based upon a one year rolling average (i.e., the average annual concentration at Plaza on July 8, 1995 is about 25 $\mu g/m^3$, which covers the period from July 9, 1994 to July 8, 1995). This was done in order to reduce seasonal variations in the concentrations and to make any trends clearer. For the period from January 1993 to May 1996, the PM_{10} levels at all but the BCR site showed a slight decline. Levels then remained the same until November 1997, increased considerably from July to October 1998, decreased again until February 2002 and have increased over the past year. Non-continuous sampling at the BCR-Warehouse was not conducted long enough to determine a trend.

Figure 4.5.8



Overall PM_{10} annual levels have declined significantly since monitoring began at Plaza in 1990. Various source management actions have likely contributed to the trend. These actions include shutdown of all beehive burners in the airshed, increased fine particulate removal in some of the pulp mill recovery and power boilers, use of coarser winter street traction material and improved street cleaning. Other future source reduction actions are identified in the Air Quality Management Plan.

Other factors such as meteorology and reduced forest fires could have contributed towards the changes in 2002 PM_{10} levels. In comparing 2001 and 2002, total precipitation was lower in 2002 than in 2001 and the number of forest fires was much higher. In the Prince George forest area, there were about 38 significant forest fires (burning 3623 hectares of forest) reported in 2002 compared to 13 fires (burning 157 hectares of forest) in 2001.

Table 4.5.13
Percentiles of the 1-hour PM_{10} Levels at the Continuous PM_{10} Monitoring Sites

Pollutant	Year	Hourly Percentile ($\mu g/m^3$)									Max. ($\mu g/m^3$)	Average ($\mu g/m^3$)	No. of Samples
		5	10	25	50	75	90	95	98	99			
Plaza	1995	4	5	10	17	29	52	73	103	130	388	24.6	8662
	1996	3	4	8	15	25	41	56	81	111	373	20.5	8577
	1997	3	5	8	14	26	43	56	76	92	208	20.2	8721
	1998	4	6	9	16	27	46	65	90	110	319	22.7	8719
	1999	2	4	7	13	22	37	51	72	87	211	17.8	8609
	2000	3	4	8	13	22	39	51	67	78	175	18.0	8692
	2001	2	4	7	13	23	39	51	69	85	170	18.2	8683
	2002	2	4	7	13	23	39	52	71	82	154	18.2	8495
BCR	1997	3	5	9	17	30	51	70	97	121	401	24.2	8706
	1998	4	6	11	20	36	58	83	126	161	582	29.1	8703
	1999	2	4	8	15	27	46	61	83	100	380	21.3	8719
	2000	2	4	8	15	26	42	55	75	93	288	20.0	8739
	2001	2	4	7	14	26	44	57	81	97	387	20.1	8634
	2002	2	4	8	15	28	48	66	91	112	430	22.1	8707
College Heights	1996	1	3	5	10	19	33	45	65	80	253	15.4	8716
	1997	1	3	5	10	19	34	44	61	73	155	14.8	8644
	1998	2	4	7	12	22	36	48	66	82	207	17.2	8643
	1999	1	2	5	9	16	28	37	50	58	140	12.7	8671
	2000	1	3	5	10	17	29	38	52	61	148	13.6	8686
	2001	1	3	5	9	18	30	40	52	63	164	13.5	8693
	2002	2	3	6	10	17	30	38	52	64	109	13.6	8696

Tables 4.5.13 and 4.5.14 show the annual distribution of the 1-hour and 24-hour PM_{10} levels expressed as percentiles for the seven years of monitoring at those sites. The percentiles give a more complete indication of trends than just annual averages, maximum values, or objective exceedances, and they can also give a better understanding as to the reasons for any trends. The Plaza site shows a decreasing trend in hourly values above the 50^{th} percentile, indicating the effect of decreasing levels on the frequency of the higher values. The 24-hour values at Plaza show an improving trend at all percentiles which is more noticeable at the higher percentiles. Even though the annual average at Plaza in 2002 was similar to the value in 2001, the 98^{th} and 99^{th} percentiles for the 24-hour levels were slightly higher. This also helps explain why the risk of respiratory deaths due to PM_{10} was slightly higher in 2001 than in 2000 (Fig. 4.5.9). The higher percentiles may have increased in 2001-2002 but the levels are still much lower that those recorded prior to 1999.

The improvement in hourly PM_{10} levels since 1998 at College Heights is not that noticeable below the 75^{th} percentile. But at the BCR site improvement is noticeable as low as the 5^{th} percentile. All sites show that the decreases in PM_{10} levels over the years are mainly due to reductions in the higher values. Hourly values at BCR exceeded 97 $\mu g/m^3$ only 1% of the time in 2001, whereas in 1997-1999 levels were over 100 $\mu g/m^3$ for 1% of the time. Also, for the 24-hour averages at BCR, values were below 55 $\mu g/m^3$ for 98% of the time in 2000 and about 90% of the time in 1998. The 99^{th} percentile for one-hour values recorded at College Heights was

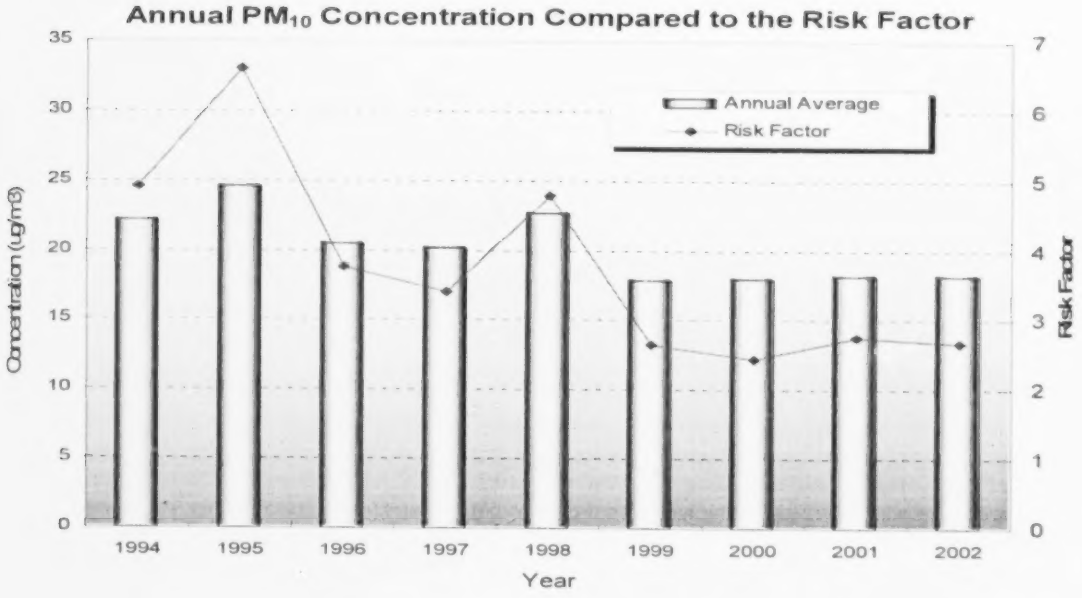
similar in 2002 to that in 2001, but the 24-hour values were much higher. The trend to reduction of the higher PM_{10} levels is most apparent in the BCR values, since 1999, but reductions have also occurred at Plaza and at College Heights. The distribution of levels demonstrates why PM_{10} health risks have decrease since the mid-90s.

Table 4.5.14
Percentiles of the 24-hour PM_{10} Levels at the Continuous PM_{10} Monitoring Sites

Pollutant	Year	24-hour Percentile (µg/m³)									Max.	Average	No. of
		5	10	25	50	75	90	95	98	99	(µg/m³)	(µg/m³)	Samples
Plaza	1995	7	9	13	19	30	48	62	83	93	120.8	24.6	8677
	1996	6	8	11	17	25	35	44	61	89	155.4	20.5	8514
	1997	7	8	11	17	26	37	47	57	65	79.1	20.2	8700
	1998	7	9	13	19	29	40	52	66	79	113.7	22.7	8728
	1999	6	7	10	14	22	34	44	53	61	97.6	17.9	8570
	2000	6	7	10	15	23	34	42	52	55	70.5	18.1	8711
	2001	6	7	10	15	23	35	43	52	58	109.6	18.2	8661
	2002	6	7	10	15	23	34	44	55	61	81.1	18.2	8459
BCR	1997	8	10	13	19	30	47	60	73	80	115.1	24.3	8708
	1998	9	11	15	23	36	57	71	92	101	127.1	29.2	8709
	1999	7	8	11	18	28	41	51	58	64	81.8	21.3	8702
	2000	6	7	11	17	26	37	46	55	62	86.3	19.9	8740
	2001	6	7	10	16	27	40	49	60	70	97.8	20.2	8699
	2002	6	8	11	17	29	45	53	61	72	88.5	22.1	8737
College Heights	1996	5	5	8	12	19	29	38	50	57	107.4	15.4	8720
	1997	4	5	7	12	19	29	39	48	54	71.3	14.9	8611
	1998	5	6	9	15	22	32	39	48	53	74.2	17.3	8636
	1999	4	5	7	11	16	24	30	36	39	46.6	12.7	8702
	2000	4	5	7	11	17	26	31	41	48	55.3	13.5	8715
	2001	4	5	7	10	18	27	33	39	46	78.0	13.5	8737
	2002	4	5	8	11	17	24	32	44	53	74.2	13.6	8737

Figure 4.5.9 shows annual average PM_{10} levels at the Plaza site in relationship to the calculated risk factor from ambient PM_{10} exposure. This information is presented to illustrate the effect of overall (not just average) levels on a PM_{10} health risk indicator. This risk factor is normalized, based on the 2000 average risk calculated for all communities in B.C. which monitor PM_{10} with a continuous monitor. The risk factors in this figure can be used to determine the potential health effects including the number of disability days for people with chronic obstructed lung diseases or asthma, the number of hospital visits due to respiratory problems, reduction in physical activity, or even death. This estimate is based on the PM_{10} concentrations for days with levels greater than 25 µg/m³ (see Health Canada, 1997). For example, a day in which the 24 hour average PM_{10} concentration was 40 µg/m³ yields 15 increments (40 – 25 = 15) and is equivalent to five days when the 24-hour concentration was 28 µg/m³ (5*(28 – 25) = 15). The annual sum of these increments is then compared to the average in B.C. for 2000 to determine the risk factor.

Figure 4.5.9



As shown in Figure 4.5.9, the risk of illnesses due to PM_{10} in 1995 was about 6.6 compared with 2.7 in 2002. This is a decrease of about 59% in the risk of health concerns due to PM_{10}. Whereas annual averages for PM_{10} decreased about 27% from 1995 to 2002. Even though the annual average in 2000 was slightly higher than that in 1999, the calculated risk due to PM_{10} was lower in 2000. This indicates the importance of reducing the frequency of the highest PM_{10} concentrations in the airshed.

4.5.3 Comparison of PM_{10} Levels with Other B.C. Locations

Figure 4.5.10 compares the 2002 PM_{10} annual averages at the Prince George continuous monitoring sites with annual averages from other sites in B.C. (only sites with greater than 75% of data capture). The sixteen highest averages were recorded at sites in the interior of B.C.. The BCR (an industrial site) and Plaza (a commercial site) sites had the fourth and seventh highest of all the sites, respectively. Gladstone had the 16th highest out of the 28 residential sites.

When comparing the same sites that monitored PM_{10} in 2001, only seven of the forty-six monitoring sites recorded a decrease in 2002. Six of these seven sites were located in northern B.C.. Dawson Creek– Harpers showed the biggest decrease and Houston Firehall reported the biggest increase in 2002. Fluctuations in both emissions and meteorology play a role in producing these year-to-year variations.

Figures 4.5.10 and 4.5.11 compare the calculated risks from ambient PM_{10} exposure between B.C. communities, with continuous and non-continuous PM_{10} monitoring, respectively. This information is presented to illustrate the effect of overall (not just average) levels on a PM_{10} health risk indicator. As previously stated, this risk factor can be used to determine the potential health effects including the number of disability days for people with chronic obstructed lung diseases or asthma, or the number of hospital visits due to respiratory problems, or decrease in physical activity, or even death. This approach shows, for example, that even though the annual average may be lower in one community than another, the health risk may be higher in that community.

Figure 4.5.10 shows that the potential risk at Williams Lake – Skyline School is almost eight times higher than the provincial average. The Plaza site has a risk that is 2.7 times higher than the provincial average. This indicates that at Plaza the risk of hospital visits due to respiratory problems, or decrease in physical activity, or even death due to PM_{10} is 2.5 times higher than the provincial average in B.C. in 2000. Annual average PM_{10} levels recorded at Gladstone School were similar to those at Langley but the risk at Gladstone was six times higher than at that site. For the non-continuous sites, Valemount recorded the highest risk which was almost ten times than the provincial average. Both figures show that a slight increase in annual averages could dramatically increase the risk of deaths due to PM_{10}.

Figure 4.5.11 compares the 2002 PM_{10} annual averages recorded at the Prince George non-continuous monitoring sites with those from other B.C. non-continuous monitoring sites with greater than 75% data capture. CNR recorded the eigth highest annual average out of the 39 non-continuous monitoring sites. Van Bien recorded the fifth highest PM_{10} annual average for the 25 residential sites (fourth highest in 2001) and Plaza had the fifth highest annual average for commercial sites (seventh highest in 2001). Only sites that were operating on the NAPS schedule (a schedule in which pollutants are monitored for a 24-hour period (midnight to midnight) once every six days) were included.

When comparing the same monitoring sites in 2001, only six of the thirty monitoring sites recorded a decrease in 2002, which was similar to that shown with the continuous monitoring sites. One of the six monitoring sites that showed a decrease was Prince George - Lakewood. Fort Nelson showed the biggest decrease in PM_{10} levels. The three sites that showed the biggest percent increase were located in northeastern B.C.

It should be noted that the non-continuous PM_{10} includes those airsheds with the highest PM_{10} levels, including Grand Forks, Vernon and Merrit, but does not include those airsheds with the lowest levels, such as those in the Lower Mainland.

Figure 4.5.10

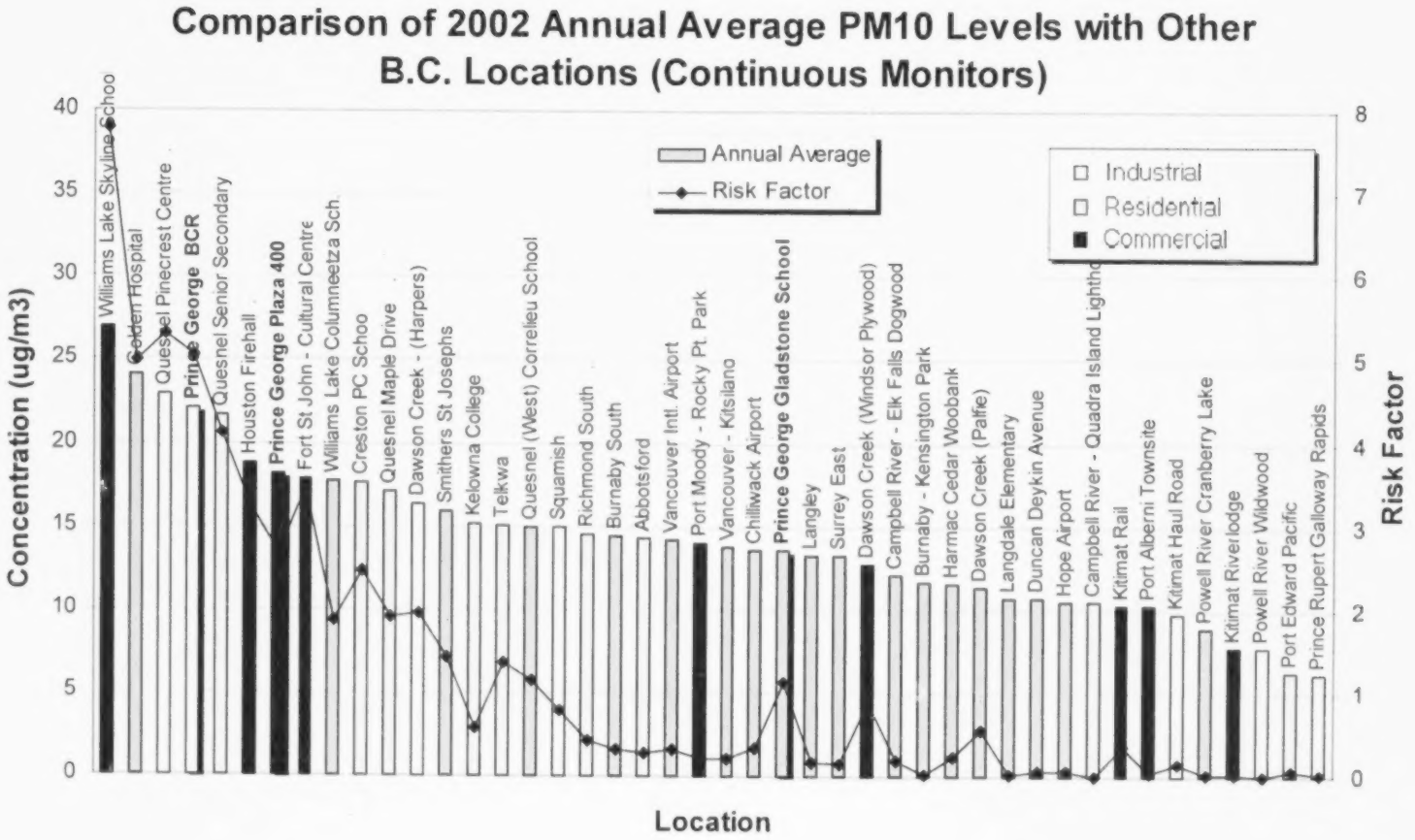
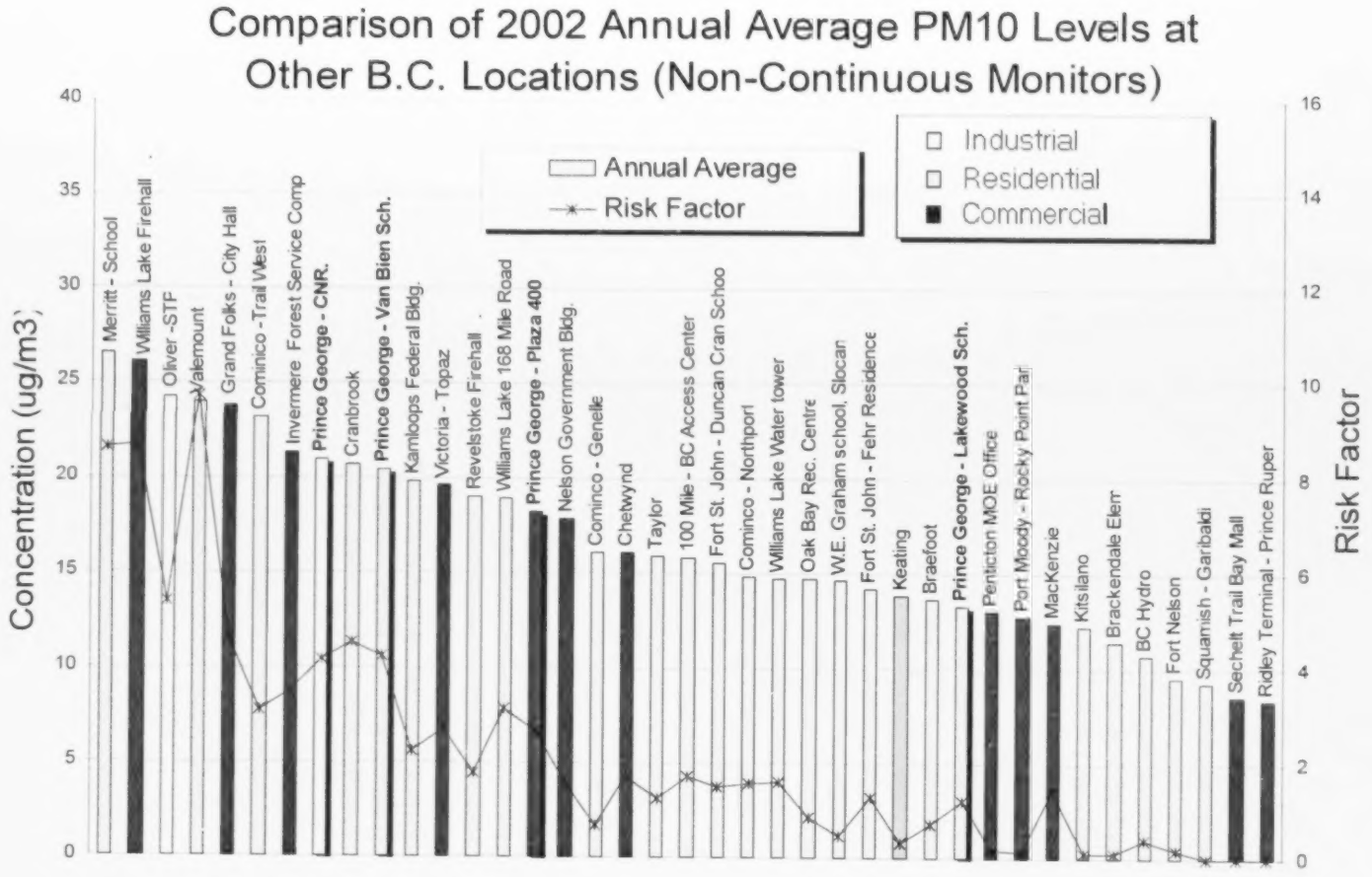

Comparison of 2002 Annual Average PM10 Levels with Other B.C. Locations (Continuous Monitors)
Concentration (ug/m3)
Risk Factor
Location
Annual Average
Risk Factor
Industrial
Residential
Commercial
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
Williams Lake Skyline Schoo
Golden Hospital
Quesnel Pinecrest Centre
Prince George BCR
Quesnel Senior Secondary
Houston Firehall
Prince George Plaza 400
Fort St John - Cultural Centre
Williams Lake Columneetza Sch.
Creston PC Schoo
Quesnel Maple Drive
Dawson Creek - (Harpers)
Smithers St Josephs
Kelowna College
Telkwa
Quesnel (West) Correlieu School
Squamish
Richmond South
Burnaby South
Abbotsford
Vancouver Intl. Airport
Port Moody - Rocky Pt. Park
Vancouver - Kitsilano
Chilliwack Airport
Prince George Gladstone School
Langley
Surrey East
Dawson Creek (Windsor Plywood)
Campbell River - Elk Falls Dogwood
Burnaby - Kensington Park
Harmac Cedar Woobank
Dawson Creek (Palfie)
Langdale Elementary
Duncan Deykin Avenue
Hope Airport
Campbell River - Quadra Island Lightho
Kitimat Rail
Port Alberni Townsite
Kitimat Haul Road
Powell River Cranberry Lake
Kitimat Riverlodge
Powell River Wildwood
Port Edward Pacific
Prince Rupert Galloway Rapids

Figure 4.5.11


Comparison of 2002 Annual Average PM10 Levels at Other B.C. Locations (Non-Continuous Monitors)
Concentration (ug/m3)
Risk Factor
Annual Average
Risk Factor
Industrial
Residential
Commercial
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12
14
16
Merritt - School
Williams Lake Firehall
Oliver -STP
Valemount
Grand Folks - City Hall
Cominco -Trail West
Invermere Forest Service Comp
Prince George - CNR.
Cranbrook
Prince George - Van Bien Sch.
Kamloops Federal Bldg.
Victoria - Topaz
Revelstoke Firehall
Williams Lake 168 Mile Road
Prince George - Plaza 400
Nelson Government Bldg.
Cominco - Genelle
Chetwynd
Taylor
100 Mile - BC Access Center
Fort St. John - Duncan Cran Schoo
Cominco - Northport
Williams Lake Water tower
Oak Bay Rec. Centre
W.E. Graham school, Slocan
Fort St. John - Fehr Residence
Keating
Braefoot
Prince George - Lakewood Sch.
Penticton MOE Office
Port Moody - Rocky Point Par
MacKenzie
Kitsilano
Brackendale Elem
BC Hydro
Fort Nelson
Squamish - Garibaldi
Sechelt Trail Bay Mall
Ridley Terminal - Prince Ruper

4.5.4 Particulate Matter ($PM_{2.5}$) Results

Recent health and medical studies have shown that the very fine particles may have more serious health impacts than coarser particles (Vedal, 1995; CEPA/FPAC Working Group, 1998; Pope et. al., 2002). These smaller particles are able to reach deeper into the lungs than coarser particles. Also, they remain longer in the atmosphere (sometimes for weeks) and are more complex chemically than the coarser particles.

Most of the $PM_{2.5}$ comes from fuel combustion from motor vehicles, space heaters and industrial facilities. The primary natural source of $PM_{2.5}$ is forest fires, due to their high temperatures. These fine particles can also be formed (as secondary pollutants) by the transformation of gaseous emissions such as SO_2, NO_x and various hydrocarbon species. Secondary particulates occur predominantly as $PM_{2.5}$. Major natural secondary $PM_{2.5}$ sources are VOCs released from trees and nitrogen oxides released from soil.

Prince George has only one $PM_{2.5}$ continuous monitor and one non-continuous monitor, both at the Plaza site. $PM_{2.5}$ is measured non-continuously by drawing air through a size selective inlet prior to collection on a teflon fibre filter at a rate of about 0.017 cubic metres per minute (Fig. 4.5.12). The sampler is run for 24 hours at a time on a 6-day cycle (i.e., once every sixth day). The continuous monitor operates in the same manner as the PM_{10} continuous monitor (Fig 4.5.2), but with a $PM_{2.5}$ selective inlet like the one shown in Fig 4.5.12.

Fig. 4.5.12 PM2.5 Partisol

The quality of the non-continuous $PM_{2.5}$ data is assessed by regular measurement of laboratory filter weighing error and by calibration of the air flow meters on the samplers. Continuous data quality is evaluated by bi-weekly field checks and quarterly mass calibrations. Data completeness was satisfactory with 99.1% valid data from the Plaza continuous monitor, and 95.1% for the non-continuous monitor.

4.5.5 $PM_{2.5}$ Continuous Monitoring Results

In September 1997 a continuous $PM_{2.5}$ monitor (a TEOM 1400a sampler) was installed at Plaza. Simultaneous continuous monitoring of PM_{10} and $PM_{2.5}$ can provide an indication of the contribution of different sources, such as combustion and road dust, to ambient levels. Table 4.5.17 shows the monthly summary of 2002 $PM_{2.5}$ data recorded at this site. Similar to the PM_{10} results at Plaza, the highest monthly averages occurred in October, November and December. This, as well as the $PM_{2.5}/PM_{10}$ ratio, is an indication that these high levels were mainly due to combustion sources rather than dust, as normally a small portion of the road dust is $PM_{2.5}$. Because the $PM_{2.5}$ level and the ratio were low in May, the high PM_{10} level in that month was likely due to a greater road dust contribution than was the case in November. The highest 2002 $PM_{2.5}$ averages were found in the late autumn.

Table 4.5.15

2002 Monthly Summary of Continuous $PM_{2.5}$ Data at Plaza

	Monthly Average ($\mu g/m^3$)	$PM_{2.5}/PM_{10}$ Ratio	Maximum Hourly ($\mu g/m^3$)	No. of Daily Values >30$\mu g/m^3$	No. of Daily Values >50$\mu g/m^3$	Maximum 24 Hour ($\mu g/m^3$)	Minimum 24 Hour ($\mu g/m^3$)
January	7.9	0.63	72	0	0	24.1	0.4
February	7.7	0.57	33	0	0	21.7	0.5
March	9.3	0.60	55	0	0	26.8	1.2
April	9.1	0.46	76	0	0	21.3	1.3
May	6.8	0.42	54	0	0	18.0	0.7
June	10.3	0.48	77	0	0	25.1	0.3
July	6.4	0.41	65	0	0	17.2	0.2
August	5.5	0.31	67	0	0	17.4	0.7
September	5.1	0.42	53	0	0	13.5	0.4
October	14.0	0.57	84	2	1	55.6	1.2
November	16.5	0.57	77	5	1	65.3	1.3
December	12.4	0.63	61	0	0	37.3	1.8
Annual	**9.2**	**0.51**	**84**	**7**	**2**	**65.3**	**0.2**

Figure 4.5.13 shows the monthly $PM_{2.5}$ averages for the four full years of continuous data from Plaza. Monthly averages in June, October, November and December 2002 were the highest ever recorded at that site for those months. Monthly averages in January, February, July, August and September were the lowest ever recorded for those months. Normally the lowest monthly averages tend to occur in May – July, but in 2002 the lowest monthly averages occurred in August to September. The long term maximums have occurred in February, but in 2002 the October and November averages were the highest indicating the significance of episodes on monthly averages. The only $PM_{2.5}$ episodes in 2002 occurred in a seven and four day period in October and November, 2002, respectively.

Figure 4.5.13

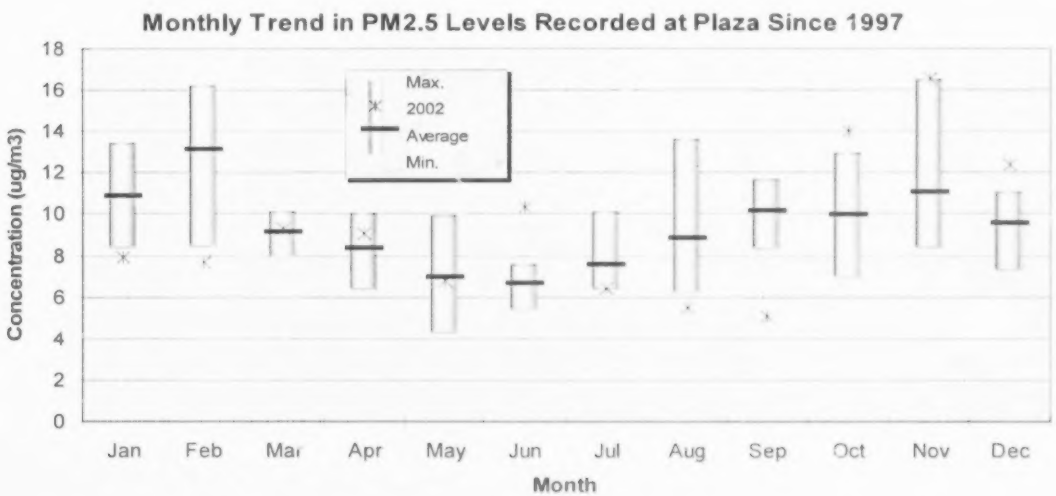
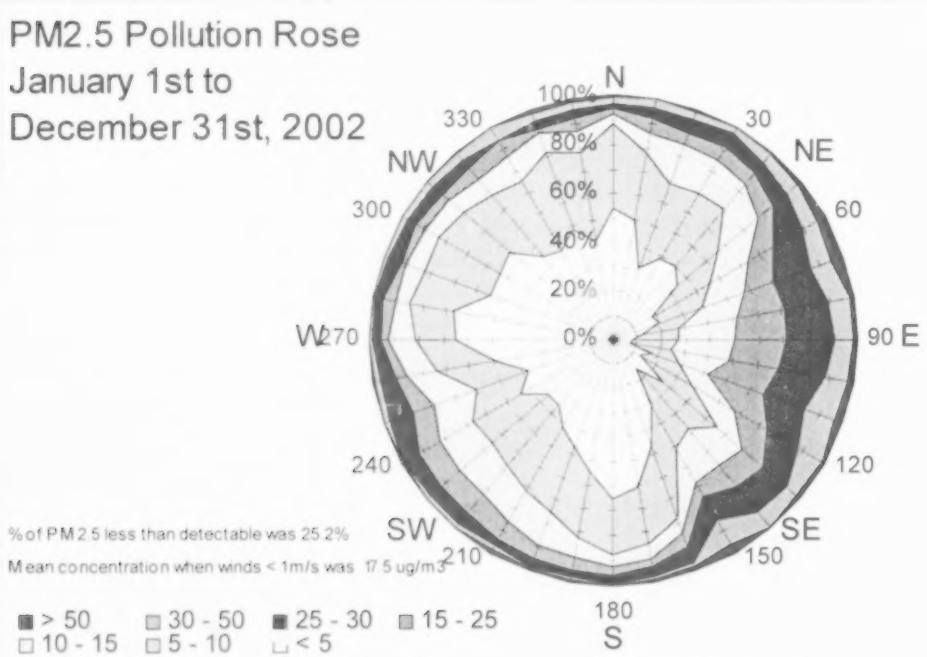


Figure 4.5.14 shows the 2002 $PM_{2.5}$ pollution rose for the Plaza site based on the meteorological data at that site. Wind directions were only considered whenever wind speeds were $\geq$ 1 m/s (winds below 1 m/s may not be strong enough to flush the pollutants out of the airshed, therefore confusing the location of the predominant source). Similar to the PM_{10} pollution rose, one-hour average particulate levels were seldom below 5 $\mu g/m^3$ when winds were blowing from the east-northeast to east-southeast sector. Also, similar to the PM_{10} pollution rose, there was a distinctive wind direction from which the highest concentrations occurred. The $PM_{2.5}$ concentration exceeded 15 $\mu g/m^3$ most often when winds were from the east-northeast to southeast sector. The most likely explanation is that winds from this sector are generally lighter, and major sources are located upwind from this monitor in that sector. Unlike SO_2 and H_2S, the $PM_{2.5}$ pollution rose shows that, although there is a dominant wind sector, significant contributions originate from other sectors as well. The average concentration when winds were less than 1 m/s was 17.5 $\mu g/m^3$ (approximately 55% of the PM_{10} level for light winds). During light winds, source sectors can not be reliably identified.

Figure 4.5.14 $PM_{2.5}$ Pollution Rose Recorded at Plaza for 2002



4.5.6 $PM_{2.5}$ Annual Trend

Table 4.5.16 and 4.5.17 show the annual trend summaries of $PM_{2.5}$ data at Plaza's non-continuous and continuous monitors, respectively. Table 4.5.16 shows a gradual and steady decrease until 1999. From 1995 through 1999 annual averages decreased about 28%. This trend was reversed in 2000, but levels in 2001 were only slightly higher than those in 1999 and levels in 2002 were only slightly lower than those in 2000 indicating the absence of a trend since 1999. Both monitors at Plaza recorded the lowest annual average in 1999 since monitoring began at that site. The 2002 maximum daily value at the continuous monitor was 65 $\mu g/m^3$ but was only 34 $\mu g/m^3$ in the non-continuous monitoring results. Yet the 2002 exceedance rate of 30 $\mu g/m^3$ level for the non-continuous monitor was about four times as high as the rate in the continuous data. These differences are likely due to a combination of factors, including the lower sampling rate; the different sampling method and random chance in the non-continuous monitoring program.

Table 4.5.16
Annual Trend Summary of Non-Continuous $PM_{2.5}$ Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 15 $\mu g/m^3$	No. (%) of Daily Values > 30 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1994	-	4(18.2%)	1 (4.5%)	52	22*
1995	13.3	19(31.1 %)	3 (4.9%)	54	61
1996	12.7	17(28.3%)	2 (3.3%)	40	60
1997	12.3	16(26.2%)	5 (8.2%)	43	61
1998	11.3	18(29.5%)	3 (4.9%)	52	61
1999	9.6	11(18.3%)	2 (3.3%)	38	60
2000	11.5	12 (19.7%)	5 (8.2%)	52	61
2001	9.9	16(26.2%)	4 (6.6%)	35	61
2002	11.2	14(23.0%)	5 (8.2%)	34	61

* Instrument installed August 1994

Table 4.5.17
Annual Trend Summary of the Continuous $PM_{2.5}$ Data at Plaza

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 15 $\mu g/m^3$	No. (%) Of Days > 30 $\mu g/m^3$	Maximum 24-Hour Average ($\mu g/m^3$)	Hours Instrument Operated
1997	-	87	15(30.1%)	6 (12.2%)	55.4	1167*
1998	9.6	119	69(18.9%)	7 (1.9%)	52.1	8722
1999	7.9	117	42(11.5%)	4 (1.1%)	34.1	8657
2000	9.5	92	61(16.8%)	11 (3.0%)	47.0	8610
2001	9.5	139	60(16.4%)	11 (3.1%)	57.9	8575
2002	9.2	84	56(15.5%)	7 (1.9%)	65.3	8685

* Monitoring started November 1997.

In July 1999, the federal government released the "National Ambient Air Quality Objectives for Particulate Matter ($PM_{2.5}$)". This established a Canada-Wide Standard for

$PM_{2.5}$ which takes effect in 2010. The $PM_{2.5}$ standard is a 24-hour averaged value of 30 $\mu g/m^3$, with achievement to be based on averaging of the annual 98th percentile over three consecutive years. For 2000-2002 the Canada-Wide Standard for $PM_{2.5}$ was exceeded in Prince George, with an average 98th percentile of 32.2 $\mu g/m^3$. Prince George was the only site in B.C. to exceed the Canada-Wide Standard for $PM_{2.5}$.

Figure 4.5.15 shows the annual trend in the levels of three types of particulate matter. To compare the different particle sizes, only days with data from each relevant non-continuous monitor were used. Up to the end of 1998, the annual average concentration of $PM_{2.5}$ was about 40% of the PM_{10} average, which was about 57% of the average total suspended particulate (TSP). Because more priority was given to PM_{10} and $PM_{2.5}$ monitoring due to recent health studies, TSP monitoring ceased in 1998 (historical data for TSP is provided in Appendix E). This graph indicates that particulate levels in all size classes gradually decreased until 1998. It is worth noting that levels of TSP and PM_{10} increased in 1998, but $PM_{2.5}$ levels continued to decrease. The 1998 annual average concentration of $PM_{2.5}$ was only about 40% of the PM_{10} average, indicating that the higher levels of TSP and PM_{10} in 1998 were due to coarser particles. The 2002 annual average concentration of $PM_{2.5}$ was about 62% of the PM_{10} average, indicating a return to more dominant fine particle sources, such as combustion emissions.

Figure 4.5.15

Table 4.5.18 shows the annual percentiles of both the 1-hour and 24-hour $PM_{2.5}$ values using the continuous monitor at Plaza for the past four years. With five full years of continuous $PM_{2.5}$ data, no trend is apparent in the $PM_{2.5}$ percentiles, which is consistent

with the annual average trend. The 50th and greater percentiles were lower in 1999 than in the other years. The percentiles for 2002 were only slightly lower than those in 2000 and 2001.

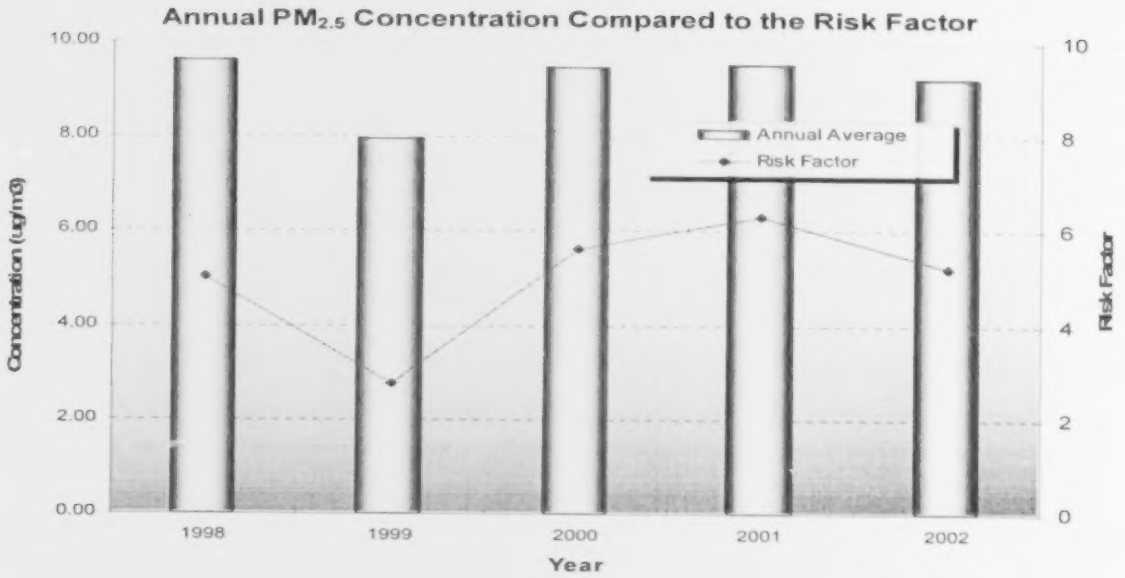
Table 4.5.18
Percentiles of the 1-hour and 24-hour Continuous $PM_{2.5}$ Levels Recorded at the Plaza Site

Pollutant	Year	Percentile (µg/m³)									Max. (µg/m³)	Average (µg/m³)	No. of Samples
		5	10	25	50	75	90	95	98	99			
1-hr													
	1998	0	1	3	7	13	21	29	40	51	119	9.62	8722
	1999	0	0	2	5	12	18	24	35	44	117	7.92	8657
	2000	0	0	3	6	13	22	31	42	50	92	9.47	8610
	2001	0	0	2	6	13	22	30	42	50	139	9.46	8575
	2002	0	0	2	6	13	22	29	40	49	84	9.22	8685
24-hr.													
	1998	2	3	5	8	13	19	22	28	38	52.1	9.63	8724
	1999	1	2	4	7	11	16	20	24	29	34.1	7.94	8658
	2000	2	2	4	7	13	19	25	32	36	47.0	9.46	8637
	2001	2	3	4	7	12	20	26	33	37	57.9	9.51	8537
	2002	2	2	4	7	12	18	22	32	38	65.3	9.21	8643

Figure 4.5.16 shows annual average $PM_{2.5}$ levels at the Plaza site in relationship to the calculated health risk factor from ambient $PM_{2.5}$ exposure. This information is presented to illustrate the effect of overall (not just average) levels on a $PM_{2.5}$ health risk indicator. This risk factor is normalized, based on the 2001 average risk calculated for all communities in B.C. which monitor $PM_{2.5}$ with a continuous monitor. This estimate is based on the $PM_{2.5}$ concentrations for days with levels greater than 15 µg/m³ (see Health Canada, 1997). For example, a day in which the 24 hour average $PM_{2.5}$ concentration was 30 µg/m³ yields 15 increments (30 – 15 = 15) and is equivalent to five days when the 24-hour concentration was 18 µg/m³ (5*(18 – 15) = 15).

As shown in Figure 4.5.16, ambient levels in 1998 were similar to those in 2000 and 2001 but the risk of illnesses due to $PM_{2.5}$ was about 15% lower in 1998. In fact, ambient levels in 1999 were about 17% lower than those recorded in 2001 but the risk of illnesses due to $PM_{2.5}$ was about 56% lower. This indicates the importance of reducing the frequency of the highest $PM_{2.5}$ concentrations in the airshed.

Figure 4.5.16



4.5.7 Comparison of $PM_{2.5}$ Levels with Other B.C. Locations

Figure 4.5.17 compares the 2002 $PM_{2.5}$ annual averages recorded at the Prince George monitoring site with annual averages from other monitoring sites in B.C. (only sites with greater than 75% of data capture were included). Because of the small number of $PM_{2.5}$ monitoring sites in B.C., both the continuous and non-continuous data are compared on the same figure. Bear Lake recorded the highest $PM_{2.5}$ annual average. The continuous (solid colour) and non-continuous (checkered colour) monitoring sites in Prince George recorded the second and third highest annual averages in the province. It should be noted that the continuous monitors at Plaza and Bear Lake sites used a different head (URG) than those at other sites (Sharp Cut). The head on the instrument separates the fine particles from the coarse particles. The Sharp Cut head has been shown to provide more accurate data. Studies have also shown that TEOMs using these heads record levels lower that those using the conventional heads. This is due to a lower percent of the coarser particles (2.5 – 5 μm) reaching the filter with the Sharp Cut head.

When comparing the same eleven continuous sites that monitored $PM_{2.5}$ in 2001, only two out of the 23 sites recorded lower $PM_{2.5}$ levels in 2002. Prince George – Plaza recorded the biggest decrease in the $PM_{2.5}$ average. Bear Lake recorded the biggest incremental increase of the non-continuous monitors, and Quesnel- Maple Drive recorded the biggest increase among the continuous monitors.

Figure 4.5.17

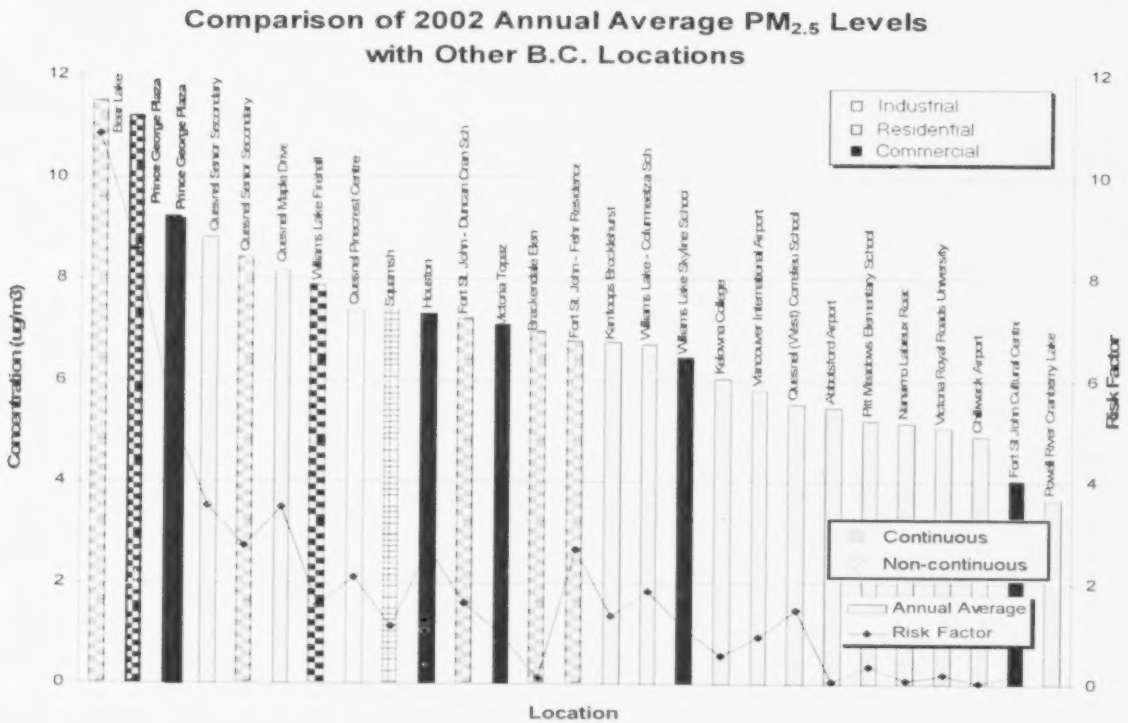


Figure 4.5.17 also shows the health risk expected each year in each community due to ambient $PM_{2.5}$. This estimate is based on the $PM_{2.5}$ concentrations for days that levels were greater than 15 $\mu g/m^3$ (see Health Canada, 1997). The comparison of risks indicates a substantial higher risk for northern interior communities. It seems that the risk calculated for the non-continuous monitors were lower than those for the continuous monitors. This could be due to the non-continuous monitors sampling on a lower frequency of days when levels were over 15 $\mu g/m^3$ than the continuous monitors. A slight decrease in $PM_{2.5}$ can make a big difference in the risk of respiratory deaths. The Prince George site recorded an annual average that was about 30% higher than Victoria, yet the risk of respiratory deaths were five times as great as that in Victoria. Again, it should be pointed out that Prince George and Bear Lake are the only two continuous $PM_{2.5}$ monitoring sites that used the conventional heads which is expected to provide higher levels than those monitors using the Sharp Cut heads.

Only Prince George recorded 98th percentile for the 24-hour average $PM_{2.5}$ that was greater than the 30 $\mu g/m^3$ Canada-Wide Standard for $PM_{2.5}$ in 2002. Prince George is the only community in B.C. that has ever recorded a 98th percentile for the 24-hour average $PM_{2.5}$ that was greater than the Canada-Wide Standard. The 24-hour average 98th percentile recorded in Prince George in 2002 was 32.0 $\mu g/m^3$.

The Ministry of Environment provides an air quality index that is updated twice daily during the work week, and that is accessible to the public via a telephone answering machine (565-6457). Air quality index values for selected pollutants are also provided to the local newspaper, radio and T.V. station on a daily basis, as well as to the Weather Network and is available on the internet at http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.summary.

When air quality deteriorates to "poor" or "very poor", the Ministry may issue air quality advisories to the public through the local news media. Advisories have been mainly limited to PM_{10} levels to date, and are issued when the rolling average 24-hour PM_{10} level exceeds the 50 $\mu g/m^3$ objective, and the meteorological forecast shows continuing limited dispersion in the airshed. We recognize that health effects from fine particulates do not show a threshold and therefore affects can occur at levels significantly lower than 50 $\mu g/m^3$. However, issuing advisories at even 25 $\mu g/m^3$ would have to be done about 10% of the year (90^{th} percentile – see Figure 4.5.15) which would blunt the effect of the advisories and consume too many resources. Ozone advisories are normally issued whenever ozone levels are expected to exceed the one-hour objective of 160 $\mu g/m^3$.

There were eight occurrences in 2002 of the 24-hour rolling average PM_{10} levels exceeding 50 $\mu g/m^3$ at the Plaza station (compared to 12 occurrences in 2000, 14 occurrences in 1999, 22 in 1998, 15 in 1997, and 10 in 1996). The duration of these occurrences ranged from 13 hours to 85 hours. Only four of these occurrences lasted 24-hours or longer. Out of these eight exceedances, only two air quality advisories were issued. Two out of the four occurrences that lasted 24-hours were included in one of the advisories. This was the lowest number of advisories to be issued in one year. However, the advisory issued on October 30^{th} was the longest advisory ever to be issued. These advisories are listed in Table 5.1 along with the duration of the episode and the maximum 24-hour average PM_{10} level recorded during this period. Advisories were not issued during other exceedances, either because the elevated levels occurred at night or on weekends when staff were not on duty, or because improvement in meteorological conditions was expected within 6 hours.

Table 5.1 Advisories Issued for Prince George in 2002

Start Date (PST)	End Date (PST)	Duration (hours)	Max. 24-hour Level ($\mu g/m^3$)
Oct. 30 16:30	Nov. 6 09:00	159	81.1
Nov. 27 16:00	Dec. 1 16:30	100	69.5

6. CONCLUSIONS

6.1 Emission Source Changes

TRS emissions from the recovery boilers and 'other sources' emissions increased at all three pulp mills from 2001 to 2002. This appears to be due to an increase in pulp production at the three pulp mills in 2002 (Table 2.1). The total TRS released by the three pulp mills increased approximately 68% from 2001.

Sulphur dioxide emissions from Intercon and P.G. Pulp decreased in 2002 from the previous year. Intercon's SO_2 emissions were only about 25% of what was emitted during the period 1991-1995. P.G. Pulp's and Northwood's SO_2 emissions were approximately 30% and 11% less, respectively, compared to the 1991-1995 emission levels Husky's SO_2 emission rate from the flare, FCC regenerator stack, foul water stripper, and process heater stacks was the second lowest ever recorded, and was about 73% lower in 2002 compared to 1997 (before the installation of the sulphur recovery unit).

Particulate emissions from all three pulp mills increased in 2002 from the previous year. Again, this may appear to be due to an increase in pulp production at the three pulp mills in 2002. Particulate emissions recorded at Intercon in 2002 were the highest recorded at that site since 1998.

Emissions of dust from downtown city streets was reduced through application of more effective dust suppression and cleaning starting in 2000. City staff have been using liquid calcium chloride to suppress dust, and adding salt to sweeper liquids to enable street sweeping to start during freezing temperatures. The result has been lower ambient PM_{10} levels in late February and during March. As a result, no air quality advisories were issued for spring dust episodes in 2000 to 2002, the first such occurrence since air quality advisories were first issued in 1995.

6.2 Air Quality Acceptability and Trends

Typically the winter and fall have poorer air quality because meteorological conditions are less favourable for dispersion of pollutants. The following trends and results were measured in 2002.

i) The annual average TRS concentrations recorded at all three currently monitored sites are some of the lowest recorded since monitoring began. The Jail site recorded the lowest frequencies of exceedances of the Level A one-hour and Level B 24-hour objectives ever recorded at that site. However, the number of hours of exceedance of the Level B 1-hour objective at the Plaza site is the highest since 1996. These exceedances of the Level B Objective at Plaza indicates the need for the additional TRS reductions called for in the Prince George Air Quality Management Plan. Monthly averages were below normal for the first nine months in 2002 at all three sites.

With the exception of 1998, the frequency of exceedance of TRS objectives has decreased since emission source changes were implemented in late 1990. The trend in annual averages shows a similar overall decrease in ambient TRS levels. The operation of foul condensate steam stripping, collection and incineration, which has reduced odorous emissions from the pulp mill effluent treatment ponds, are responsible for most of this reduction in exceedances. The Air Quality Management Plan calls for the identification of other reduction sources to further improve compliance with the air quality objectives, particularly in the downtown.

ii) Since the installation of a sulphur recovery unit at Husky in November 1997, average ambient SO_2 levels have decreased by about 50%. In 2002, ambient SO_2 levels exceeded the provincial one-hour objective four times at the CBC site and once each at the Plaza and Jail sites. Neither monitoring site exceeded the daily Level A objective in 2002. It is believed that the Jail site is affected more by Husky's flare than the CBC site. Monthly averages in 2002 were below normal for at least ten months at all three sites.

iii) The annual average NO_2 level at Plaza was the lowest recorded at that site. Monthly averages were below normal for all months in 2002. Since the replacement NO_2 monitor was installed there seems to be a decreasing trend in the NO_2 levels.

iv) The annual average ozone level recorded at Plaza was the second highest ever recorded, but the number of hours of exceedances of the Level A 1-hour objective recorded at that site were the lowest recorded since 1997. The number of daily exceedances of the Level A and B objectives in 2002 were the most ever recorded at that site. With six complete years of data, it appears that ozone has been gradually increasing. The monthly averages for nine months in 2002 were above normal for those months.

v) Annual average PM_{10} levels in 2002 were higher than those in 2001 at three out of the four non-continuous monitoring sites. Levels in 2002 at Plaza and CNR were similar to those in 1999. Lakewood recorded the lowest annual average since monitoring began at that site.

Annual average 2002 continuous PM_{10} levels at Plaza and Gladstone were similar to those in 2001, whereas at BCR the average was about 10% higher. No sites recorded exceedances above 100 $\mu g/m^3$ in 2002. The frequency of exceedances of the Level B objective were the highest since 1998 at all three sites. All three continuous monitoring sites recorded monthly averages for the first five months in 2002 that were below normal for those months, and recorded monthly averages for the last three months in 2002 that were above normal for those months.

vi) The annual average $PM_{2.5}$ level at Plaza continuous monitor was slightly lower than the previous year, but the non-continuous monitor recorded a much higher annual average than the previous year. Since 1995, annual averages gradually decreased at Plaza until 1999 as measured with the non-continuous monitor. The continuous monitor, installed in late 1997, has not produced a noticeable trend.

6.3 Recommendations

i) Add non-continuous $PM_{2.5}$ to Van Bien and Lakewood PM_{10} monitoring sites,

ii) Increase the frequency of PM_{10} non-continuous monitoring at Van Bien, Lakewood, CNR and Plaza to once every three days,

iii) Add continuous $PM_{2.5}$ monitoring at Gladstone, along with meteorological data and continuous SO_2 to enable the sources of episodic and average PM levels to be identified, and

iv) Add continuous $PM_{2.5}$ monitoring at CBC to help in determining the PM contribution from pulp mills.

7. REFERENCES

Altshuller, Paul A., Lefohn Allen S., *Background Ozone in the Planetary Boundary Layer Over the United States*, Journal of Air and Waste Management Association, Vol. 46, p134-141, ISSN 1047-3289.

Atmospheric Environment Service, *Monthly Meteorological Summaries, Prince George Airport*, Environment Canada, 1986-2003.

BC Ministry of Environment, *2001 Annual Air Quality Report for Prince George*. Prepared for the Prince George Ambient Air Technical Committee by Environmental Protection BC Environment, Prince George, April 2003.

BC Ministry of Environment, 1992. *Smoke Management For The 90's*. Queens Printer, Victoria, B.C. ISBN 0-7726-1437-7.

BC Ministry of Environment, April 1992. *Ensuring Clean Air*. Queens Printer, Victoria, B.C. ISBN 0-7726-1497-0.

BC Ministry of Environment. March 1997. *Air Quality Report for British Columbia: Fine Particulate (PM_{10}) Levels (1990-1995)*. Air Resources Branch, Victoria, B.C.

Breed, Christine, 1998, *Characterization and Source Apportionment of Particulate Matter Less Than 10 Microns in Diameter in the Prince George Airshed*, The University of Northern British Columbia, Prince George.

Brimblecombe, Peter, *Air Composition & Chemistry, 2nd Edition*, Cambridge University Press, Cambridge, 1996.

Browell, E.V., et. al., *Ozone and Aerosol Distributions in the Summertime Troposphere over Canada*, Journal of Geophysical Research, Vol. 99, p1739-1755, 1994.

Bytnerowicz, Andrzej, Dueck, T., Godzik, S., *Recognition of Air Pollution Injury to Vegetation, A Pictorial Atlas, Nitrogen Oxides, Nitric Acid Vapor, and Ammonia*, 2nd Edition, Air & Waste Management Association, Pittsburgh, 1998, ISBN 0-923204-14-8.

CEPA/FPAC Working Group on Air Quality Objectives. *National Ambient Air Quality Objectives for Particulate Matter. Executive Summary*, Health Canada/Environment Canada, 1998. ISBN 0-662-63486-1.

Finlayson-Pitts, B.J., Pitts, J.N., *Atmospheric Chemistry: Fundamentals and Experimental Techniques*, Wiley-Interscience, New York, 1986

Godish, Thad, 1991. *Air Quality* - Second Edition, Lewis Publishers, Inc.

Government of B.C., *Selected Vital Statistics and Health Status Indicators. Annual Report 1998*, Division of Vital Statistics of B.C.

Health Canada, Environment Canada, *National Ambient Air Quality Objectives for Particulate Matter, Addendum to the Science Assessment Document.* December 1997, ISBN 0-662-28088-1.

Krupa, Sagar V., Tonneijck, A. Manning, W.J., *Recognition of Air Pollution Injury to Vegetation, A Pictorial Atlas. Ozone*, 2nd Edition, Air & Waste Management Association, Pittsburgh, 1998, ISBN 0-923204-14-8.

Legge, Alan H., and Sagar, Krupa V., editors, 1990., *Acidic Deposition: Sulphur and Nitrogen Oxides.* The Alberta Government/Industry Acid Deposition Research Program (ADRP), Lewis Publishers, Inc.

Millipore Corporation, *Waters Sep-Pak DNPH-Silica Cartridge, Care and Use Manual* , Waters Chromatography Publications, Milford, MA., 1992

Office of Air Quality Planning and Standards, *1996 National Air Quality and Emissions Trends Report*, US Environmental Protection Agency, Research Triangle Park, NC., July 1998.

Ontario Ministry of Environment and Energy, December 1995, *Air Quality in Ontario, 1994 Comprehensive Report*, Queen's Printer for Ontario, Toronto, Ont. ISSN 0840-9366

Pope, C. Arden, Burnette, Richard T., Thun, Michael J., Calle, Eugenia E., Krewski, Daniel, Ito, Kazuhiko, Thurston, George D. *Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution*, Journal of American Medical Association, p. 1132-1141, Vol. 287, No. 9, March 2002.

Prince George Airshed Technical Management Committee, *Prince George Air Quality Management Background Report*, October, 1996.

Prince George Airshed Technical Management Committee, *Prince George Air Quality Management Plan - Phase One - Final Draft*, December, 1998.

Stern, Arthur C., Boubel, Richard W., Turner, D. Bruce, Fox, Donald L., *Fundamentals of Air Pollution, 2nd Edition*, Academic Press, London, 1984.

Subcommittee on Hydrogen Sulphide, *Hydrogen Sulphide*, University Park Press, Baltimore, 1979.

USEPA, 1988. *Introduction to PM_{10} SIP Development*. Student Workbook for APTI Course SI:451. Prepared by Air Pollution Training Institute, Research Triangle Park, North Carolina.

Vedal, Dr. Sverre 1993. *Health Effects of Wood Smoke: A Report to the Provincial Health Officer of British Columbia*, September 1993.

Vedal, Dr. Sverre, Blair J., Manna B., *Adverse Respiratory Health Effects of Ambient Particle Exposure*. Proceedings AWMA 84th Annual Meeting, B.C. Vancouver 1991; 91-180.56.

Vedal, Dr. Sverre, June 1995. *Health Effects of Inhalable Particles: Implications for British Columbia*. Prepared for Ministry of Environment, Lands and Parks. Department of Medicine, University of British Columbia, Vancouver, B.C.

World Health Organization. 1987. *Air Quality Guidelines for Europe*. Regional Office for Europe, Copenhagen, Denmark. WHO Regional Publications, European Series No. 23.

World Health Organization Geneva 1989, *Environmental Health Criteria 89 - Formaldehyde*, United Nations Environment Programme, the International Labour Organization, and the World Health Organization, Finland, 1989.

APPENDIX "A"

B.C. Ambient Air Quality Objectives

Air quality objectives of B.C. are generally based on objectives set by the Federal Government in the Clean Air Act. The objectives are based on protecting human health and protecting the environment. Objectives are often set at three levels.

Level A — Maximum Desirable for the long-term goal for air quality and forms the basis for anti-degradation policy for the pristine parts of the country and for continuing development of control technology.

Level B — Maximum Acceptable is intended to provide adequate protection against the effects of pollution on soil, water, vegetation, materials animals, visibility, personal comfort and well being.

Level C — Maximum Tolerable denotes time based concentrations of air contaminants beyond which, due to diminishing margins of safety, appropriate action is required without delay to protect the health of the general population.

Table A -1
Provincial Air Quality Objectives ($\mu g/m^3$)

	Averaging Period	Level A	Level B	Level C
Total Reduced Sulphur	1 hour	7.5	28	42
	24 hour	4	6	7.5
Sulphur Dioxide	1 hour	450	900	1300
	24 hour	160	260	360
	Annual	25	50	80
Nitrogen Dioxide	1 hour		400	1000
	24 hour		200	300
	Annual	60	100	
Total Suspended Particulate (TSP)	24 hour	150	200	260
	Annual	60	70	75
Particulate Matter (PM_{10})	24 hour		50	
Formaldehyde (HCHO)	1 hour	60		
Lead in TSP	24 hour	4	4	6
	Annual	2	2	3
Ozone	1 hour	100	160	300
	24 hour	30	50	
	Annual		30	
Carbon Monoxide	1 hour	14,300	28,000	35,000
	8 hour	5500	11,000	14,300

Appendix "B"

Industry Shutdowns

Table B-1 shows pulp mill shutdowns since 1991. For the purpose of this report a shutdown is defined as a total mill shutdown (or zero TRS and SO_2 stack emissions) for periods of 24 hours or longer. Note: previous issues of this report included shutdown periods from 1982 but these have been reduced for brevity. In 2001 none of the three pulp mills were shutdown at the same time.

TABLE B-1
Pulp Mill Shutdown Periods

Year	Northwood	Intercontinental	P.G. Pulp
1991	Jan. 1 Sep. 1 - Sep. 6	Jan. 1 - Jan. 2 Mar. 12 - Mar. 13 Apr. 14 - Apr. 20 Sep. 1 - Sep. 23 Nov. 11 - Nov. 13 Dec. 23 - Dec. 27	Jan. 14 - Jan. 17 May 5 - May 11 Sep. 1 - Sep. 3 Oct. 20 - Oct. 27 Nov. 1 - Nov. 3 Dec. 23 - Dec. 27
1992	Jun. 15 - Jul. 21 Sep. 7 - Sep. 8 Dec. 24 - Dec. 27	Apr. 10 - Apr. 17 Jun. 14 - Jun. 20 Sep. 7 - Sep. 14 Dec. 24 - Dec. 27	May 4 - May 9 Jun. 14 - Jun. 20 Sep. 7 - Sep. 9 Oct. 26 - Oct. 31 Dec. 24 - Dec. 27
1993	Aug. 28 - Sep. 11 Dec. 24 - Dec. 27	Mar. 15 - Mar. 28 Aug. 6 - Sep. 12 Dec. 24 - Dec. 26	Mar. 15 - Mar. 28 May 16 - May 21 Sep. 6 Oct. 17 - Oct. 22 Dec. 24 - Dec. 26
1994	Sep. 27 - Oct. 2 Dec. 24 - Dec. 27	Feb. 18 May 10 - May 11 Aug. 21 - Sep 19 Dec. 24 - Dec. 26	Apr. 17 - Apr. 22 Aug. 22 – Sep. 6 Oct. 20 - Oct. 24 Dec. 24 - Dec. 26
1995	Sep. 16 - Sep. 18 Sep. 27 - Sep. 30. Dec. 24 - Dec. 27	Aug. 23 - Aug. 30 Dec. 24 - Dec. 26	Oct. 17 - Oct. 23 Dec. 24 - Dec. 26
1996	Mar.15 - Apr. 2 Oct. 2 - Oct. 9 Dec. 24 - Dec 27	Apr. 9 - May 10 Aug. 12 - Aug. 23 Dec. 22 - Dec. 26	Sep. 17 - Sep. 24 Dec. 24 - Dec.26
1997	May 5 - May 16 Dec. 24 - Dec. 27	May 3 - May 11 Dec. 24 - Dec 26	Sep. 29 - Oct. 5 Dec. 24 - Dec. 26
1998	Apr. 02 - Apr. 09 Dec. 24 - Dec. 27	May 4 - May 12	Sep. 14 - Sep. 20
1999	June 05-June 11	May 10-May 17 Sep. 15	Sep. 26-Oct. 6
2000	May28 - June 05	Apr. 26 - May 4 Sep. 13	Sep. 26 - Oct. 1
2001	Sept. 23 - 28	May 3 – May 16	Apr. 1 – Apr. 13
2002	Sept. 20 – Oct. 2	May 25 - June 2	Apr. 8 – Apr.17

Table B-2 lists the dates when the various major emission sources at the Husky Oil Refinery were shutdown for 24 hours or more from 1991 to 2002. Note: previous issues of this report included shutdown periods from 1982 to 1990 but these have been reduced for brevity.

Husky Oil's refinery shutdowns exceeding 24 hours in 2002 were limited to:

- The crude and unifiner maintenance shutdown from April 25 to May 15 and April 25 to May 17, respectively.
- The fluid catalytic cracking unit (FCCU) was shutdown on April 21-May 14, May 17-18, and December 10.
- Major problems with the Sulphur Recovery Unit caused that unit to be shut down from April 25 to June 16.

Table B-2
Husky Refinery Shutdown Periods

Year	FCCU	Reformer	Unifiner	Crude	Sulphur Plant
1991	Apr.24 - May 6 Aug. 24-26 Nov. 11-13	Apr.13 - May 8 Aug. 12-26	Apr.13-May 8 Aug. 12-26 Nov. 13 Dec. 18	Apr.13 - May 7 Aug. 12-26 Nov. 13 Dec. 18	-
1992	Jun. 5-27 Oct. 12-16	May 22-Jun 18 Nov. 18-25	May 22-Jun 18 Jun. 1-18 Nov. 18-25	May 22-Jun 18 Nov. 18-25	-
1993	Apr.26 - May 17 Dec. 1-5	Apr. 14-28	Apr.14-May 2	Apr.14-May 2	-
1994	Apr.14 - May 8 Jun. 1-8	Apr. 10-29	Apr.10-May 2	Apr.10-May 2	-
1995	Jan. 27-Feb. 8 Apr.17-May14	Apr. 15-30	Jan. 27-Feb 1 Apr. 15-30	Jan 27-Feb 1 Apr. 15-30	-
1996	Apr.16-May14 Aug.14-15 Dec. 25-28	Apr. 16-30	Apr.15- May 5 Aug.14	Apr.15-May 5 Aug. 14	-
1997	May 29-Jun.18		May 23-31	May 23-31	Nov.20
1998	Feb. 26 – 28 Apr.28-May 17 Oct. 24-.28	Apr1 6 – May 4	Apr 16- May 8 Jul 29- 30	Apr 16 – May 8 Jul 29- 30	Apr 24-May 16 Jul 29-30
1999	Apr. 20-May 10 Nov. 01-03 Nov. 10	Apr.17-30	Apr.17-May 1	Apr.17-May 1	Apr.18-May 13
2000	Apr. 8-14 July 30-31 Sep. 5-15	Jun. 8-20	Apr. 30 Jun. 8-21	Apr.30-May 2 Jun. 8-21	Jun.19-20
2001	Feb. 11 July 28-31 Aug. 12-21	Jul.25 – Aug.4	Jul.25 – Aug.5	Jul.25 – Aug. 5	Jul.28 – Aug. 4
2002	Apr. 27-May14 May17-18 Dec. 10	Apr. 25-May14	Apr. 25-May17	Apr. 25-May15	Apr. 25-Jun.16

Appendix C

Industrial Operating Rates

The sources of the gaseous contaminants measured in Prince George by this monitoring program include three pulp mills and the oil refinery. The principle gaseous contaminants are total reduced sulphur (TRS) and sulphur dioxide (SO_2). TRS is primarily emitted from the pulp mills, while both the oil refinery and the pulp mills are the principle sources of SO_2. Other minor sources of sulphur are also present in the Prince George bowl area which may influence a nearby monitoring station.

Particulate sources include the pulp mills, sawmill operations, road dust from vehicle movement, slash burning, residential fireplaces, gravel pits, etc.

Ambient levels depend mainly on meteorology and emission rates. These emission rates can depend on the operating rate at each industrial site, which may come from several sources located at these sites. Details of the various process capacities for the three pulp mills and the oil refinery are shown in Tables C-1 and C-2, respectively.

Table C-1
Typical Operating Rate of Pulp Mills in 2002 (Tonnes/day)

	Pulp Mills		
Process Units	**Intercon**	**P. G.**	**Northwood**
Total Pulp	864	748	1548
Digester	866	795	1491
Dryers	864	748	1548
Evaporators	866	795	1491
Recovery Boilers	866	795	1491
Lime Kilns	250 (as CaO)	214 (as CaO)	434 (as CaO)

CaO - Calcium Oxide

Table C-2
2002 Husky Refinery Typical Operating Rate

	Operating Rates		
Process Units	**m^3/day**	**Barrels/day**	**Tonnes/day**
Crude Unit	1,723.4	10,840	
Unifiner	1,290	8,114	
Catalytic Cracking Unit	512	3,221	
Reformer	260.3	1,637	
Sulphur Recovery Unit	-		4.49

Appendix "D"

Monitoring Program Notes

i) Continuous Monitor Audit Results

Multi-point (five point) calibrations are performed monthly in addition to audit checks. The continuous monitor audit (the five-point average) results are listed below (instrument calibration drifts are listed in percentages). In 2002, according to the two audits performed during the year (April and October), all continuous monitors performed within the allowable instrument deviation of plus or minus 15% as determined by an auditor from the Ministry of Water, Land and Air Protection.

Table D - 1
2002 Continuous Monitor Audit Results

Pollutant	Station	April	Oct.
TRS (ML 8850)	Plaza	+4.4%	+13.7%
	Lakewood School	+5.8%	-1.2%
	Jail	+5.5%	+13.1%
SO_2 (ML 8850)	Plaza	-2.1%	+6.3%
	CBC	+6.0%	+3.8%
SO_2 (TECO 43A)	Jail	+6.2%	+7.5%
O_3 (API 400)	Plaza	+8.2%	+3.8%
NO_2 (TECO 42)	Plaza	-8.7%	+1.0%
PM_{10} (TEOM)	Plaza	-0.8%	-1.9%
	BCR	-3.7%	-2.3%
	Gladstone	+0.7%	-5.8%
$PM_{2.5}$	Plaza	-1.2%	-2.2%

ML 8850 - Monitor Lab 8850 Analyzer and STI Thermal Oxidizer

Excellent	$\leq \pm 5\%$
Satisfactory	$\pm 5\%$ to $\pm 15\%$
Unsatisfactory	$\geq \pm 15\%$

ii) Instrument Operating Hours

Table D-2 shows the percent of valid monitoring time at each station. Within the 8760 monitoring hours in a year, ambient air analyzers require both scheduled and unscheduled maintenance to maintain the instrument's calibration and sensitivity to the appropriate standard. Hours of monitoring are reduced by automated daily calibrations, manual weekly calibrations and monthly five point calibrations, annual audits, as well as power failures, instrument malfunction and occasional operator error.

Due to scheduled daily and monthly calibrations, the highest percent valid time available would be 96% for all monitors except the TEOMs . A monitor with a low percent valid time may bias the monitoring results, especially if the pollutant monitored is seasonally dependent. 75% of 8760 hours (6570 hours) is considered acceptable as actual instrument operating hours.

Table D - 2
Instrument Percent Valid Data for 2002

Pollutant	Station	% of Valid Data
TRS	Plaza	93.2%
	Lakewood	94.2%
	Jail	95.6%
SO_2	Plaza	95.5%
	Jail	95.5%
	CBC	95.3.%
O_3	Plaza	98.1%
PM_{10}	Plaza	97.0%
	Gladstone	99.3%
	BCR	99.7%
NO_2	Plaza	93.3%
$PM_{2.5}$	Plaza	99.1%

iii) Instrument Malfunctions

No problems were noted in 2002 that resulted in < 75% valid data.

Appendix "E"
Archived data

The propose of this section is to provide additional information on other monitoring programs that existed at one time in the Prince George airshed. These programs were either set up for several reasons. There were case studies in which there was an attempt to capture high episode periods. Some monitors were moved to a new location of replaced with more advance monitors. Other monitoring ceased either due to funding, or levels in those areas were not high enough to be a concern.

E.1 Additional TRS Results

Due to improvement in TRS emissions from the industrial sites, it was felt that the five TRS monitors could be reduced to three and still provided sufficient information. Therefore the Foreman Flat and Van Bien sites were chosen to be removed from the monitoring program.

The monitor at the Glenview site was installed to determine the frequency of TRS exceedances that may be occurring at that site. Levels were low enough that it was felt there was not a need to continue monitoring at that site.

Table E.1.1
Annual Trend Summary of TRS Data at Foreman Flats

	Annual Average	No. (%) of 1-Hour Values		Maximum Hourly Average	No. (%) of Daily Values		Maximum Daily Average	No. of hours Instrument
Year	($\mu g/m^3$)	>7$\mu g/m^3$	>28$\mu g/m^3$	($\mu g/m^3$)	>3$\mu g/m^3$	>6$\mu g/m^3$	($\mu g/m^3$)	Operated
1982	-	847 (21.3%)	149 (3.7%)	177	106 (63.9%)	72 (43.4%)	28.2	3978*
1983	7.2	1803 (22.8%)	426 (5.4%)	326	244 (73.9%)	163 (49.4%)	43.7	7917
1984	7.2	1728 (22.5%)	351 (4.6%)	531	203 (63.6%)	140 (43.9%)	147.7	7664
1985	7.6	1526 (22.2%)	406 (5.9%)	170	186 (65.0%)	142 (49.7%)	36.1	6860
1986	9.2	1968 (26.0%)	529 (7.0%)	404	235 (74.6%)	173 (54.9%)	114.4	7568
1987	10.0	2485 (30.2%)	706 (8.6%)	177	278 (76.2%)	226 (61.9%)	46.7	8242
1988	9.4	2328 (28.6%)	673 (8.3%)	290	273 (74.6%)	207 (56.6%)	58.9	8134
1989	9.4	1871 (26.7%)	530 (7.6%)	312	215 (58.9%)	142 (38.9%)	71.0	7005
1990	3.7	1160 (17.6%)	95 (1.4%)	106	122 (33.4%)	56 (15.3%)	16.4	6599
1991	2.1	537 (6.6%)	12 (0.1%)	69	80 (21.9%)	17 (4.7%)	12.1	8091
1992	2.2	586 (7.2%)	25 (0.3%)	88	91 (24.9%)	24 (6.6%)	12.9	8178
1993	2.6	632 (7.7%)	41 (0.5%)	85	93 (25.5%)	30 (8.2%)	28.7	8187
1994	2.2	613 (7.5%)	10 (0.1%)	64	89 (24.4%)	16 (4.4%)	12.0	8206
1995	--	147 (7.2%)	4 (0.2%)	42	25 (27.8%)	5 (5.6%)	13.1	2043**

* Instrument Operated June - December 1982
**Instrument moved at the end of March 1995

Table E.1.2
Annual Trend Summary of TRS Data at Van Bien

Year	Annual Average ($\mu g/m^3$)	No. (%) of 1-Hour Values >7$\mu g/m^3$	No. (%) of 1-Hour Values >28$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Daily Values >3$\mu g/m^3$	No. (%) of Daily Values >6$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of hours Instrument Operated
1982	-	370 (8.8%)	128 (3.0%)	99	47 (26.7%)	29 (16.5%)	36.9	4224*
1983	5.7	1148 (14.8%)	432 (5.6%)	127	119 (36.8%)	91 (28.2%)	67.0	7761
1984	2.3	510 (6.9%)	140 (1.9%)	92	64 (20.7%)	41 (13.3%)	30.0	7423
1985	3.4	699 (9.3%)	277 (3.7%)	170	86 (27.4%)	50 (16.0%)	48.5	7509
1986	4.5	1198 (14.5%)	468 (5.7%)	120	127 (36.9%)	86 (25.0%)	55.0	8266
1987	4.4	1129 (13.8%)	445 (5.5%)	170	111 (34.8%)	75 (20.5%)	71.3	8159
1988	3.7	1137 (13.9%)	353 (4.3%)	227	107 (29.2%)	77 (21.0%)	71.9	8207
1989	3.2	754 (10.4%)	223 (3.1%)	163	80 (21.9%)	46 (12.6%)	39.5	7245
1990	1.1	456 (5.6%)	40 (0.5%)	57	48 (13.2%)	18 (4.9%)	16.7	8215
1991	1.2	487 (6.0%)	13 (0.2%)	42	44 (12.1%)	22 (6.0%)	22.9	8119
1992	1.4	599 (7.3%)	22 (0.3%)	55	57 (15.6%)	24 (6.6%)	16.4	8159
1993	1.6	646 (8.0%)	37 (0.5%)	42	56 (15.3%)	32 (8.8%)	25.4	8098
1994	1.2	502 (6.1%)	9 (0.1%)	40	47 (12.9%)	22 (6.0%)	15.9	8296
1995	--	238 (10.0%)	2 (0.1%)	30	27 (26.0%)	9 (8.7%)	12.7	2371**

*Instrument Operated June - December 1982
**Instrument moved in early April 1995

Table E.1.3
Annual Trend Summary of TRS Data at Glenview*

Year	Annual Average ($\mu g/m^3$)	No. (%) of 1-Hour Values >7$\mu g/m^3$	No. (%) of 1-Hour Values >28$\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Daily Values >3$\mu g/m^3$	No. (%) of Daily Values >6$\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of hours Instrument Operated
1998	-	14 (0.3%)	0 (0%)	18	0 (0%)	0 (0%)	2.8	4635
1999	-	0 (0%)	0 (0%)	6	0 (0%)	0 (0%)	2.1	4305

*Instrument Operated June 1998 – July 1999

E.2 Additional SO_2 Results

Due to the low SO_2 levels recorded at the Gladstone site in College Heights, it was felt that there was not a need to continue monitoring SO_2 at that site. Monitoring was discontinued in March 1999.

Table E.2.1
Annual Trend Summary of SO_2 Data at College Heights

Year	Annual Average ($\mu g/m^3$)	No. of 1-Hour Values > 450 $\mu g/m^3$	Maximum Hourly Average ($\mu g/m^3$)	No. of Daily Values > 160 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	No. of Hours Instrument Operated
1995	-	0	269	0	96.3	5,430*
1996	10.5	0	280	0	85.4	8,370
1997	10.5	0	314	0	148.5	8,351
1998	7.9	0	160	0	76.5	8,269
1999	-	0	205	0	59.1	1,424**

*Instrument installed May 1995
**Instrument removed March 1999

E.3 Additional PM_{10} Results

Non-continuous monitors at the Gladstone and BCR-Warehouse sites were replaced with the continuous TEOM monitors. The monitor at BCR-Engineering building was relocated to the BCR-Warehouse because the Engineering building was removed from that site. Prior to the PM_{10} monitor being relocated to the BCR-Warehouse, co-located monitors were located at the Warehouse and the Engineering building to determine how much of a difference this new location would make. The BCR-Warehouse site PM_{10} levels were lower than those from the BCR-Engineering Building site which was due to the new site being located on a taller building and further from unpaved roads.

The Hart Highlands monitoring site was a temporary mobile site on loan from the Federal Ministry of Transportation. Another site in the Hart, located at the Glenview school, was discontinued in February 2001, since low levels showed that PM_{10} was not a main concern in that location. Data were collected at the Sintich Trailer Park (Table E.3.5), from December 1995 to June 1997, to provide a baseline for the planned Canfor MDF (Medium Density Fibreboard) project, which has not proceeded.

Table E.3.1
Annual Trend Summary of Non-Continuous PM_{10} Data at Gladstone

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1992	-	1 (3.2%)	0	54	31*
1993	25.8	5 (8.8%)	1 (1.8%)	122	57
1994	16.8	0	0	50	60
1995	16.7	2 (3.3%)	0	63	60
1996	15.4	0	0	49	61
1997	15.3	1 (1.7%)	0	57	61
1998	20.2	2 (3.3%)	0	57	61

- Note: Monitoring started June 5, 1992.

Table E.3.2
Annual Trend Summary of Non-Continuous PM_{10} Data at the BCR-Engineering Bldg.

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1990	-	8 (21.6%)	3 (8.1%)	132	37
1991	-	8 (50.0%)	1 (6.3%)	122	16*
1992	-	2 (9.1%)	0	76	22**
1993	43.2	17 (28.8%)	2 (3.4%)	147	59
1994	38.4	12 (21.1%)	2 (3.5%)	143	57
1995	40.9	16 (31.4%)	3 (5.9%)	181	51
1996	-	11 (29.7%)	2 (5.4%)	153	37***

* Note:Station relocated to CNR site May 6, 1991.
** Note:Monitoring re- started July 29, 1992.
***Note: Station closed August 20,1996 and relocated to BCR-Warehouse

Table E.3.3
Annual Trend Summary of Non-Continuous PM_{10} Data at the BCR-Warehouse

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1996	-	4 (11.4%)	0	79	35*
1997	26.0	4 (7.1%)	0	75	61
1998	31.8	10 (16.4%)	0	92	61

* Note: Monitoring started June 2, 1996.

Table E.3.4
Annual Trend Summary of Continuous PM_{10} Data at the Hart Highlands

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 50 $\mu g/m^3$	No. (%) Of Days > 100 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	Hours Instrument Operated
1997	15.1	210	1 (0.4%)	0	53	6,685*
1998	-	567	8 (9.8%)	3 (3.7%)	144	1,926**

* Note: Monitoring started April 5, 1997.
** Note: Monitoring ended March 22, 1998.

Table E.3.5
Annual Trend Summary of Continuous PM_{10} Data at Glenview School - Hart

Year	Annual Average ($\mu g/m^3$)	Maximum Hourly Average ($\mu g/m^3$)	No. (%) of Days > 50 $\mu g/m^3$	No. (%) Of Days > 100 $\mu g/m^3$	Maximum Daily Average ($\mu g/m^3$)	Hours Instrument Operated
1998	-	117	0	0	38	4,852*
1999	9.2	221	0	0	27	8,670
2000	9.9	153	0	0	49	8,731
2001	-	137	2 (4.4%)	0	77	1,090**

* Monitoring started June 1998.
** Monitoring ended February 2001.

Table E.3.6
Annual Summary of Non-Continuous PM_{10} Data at the Sintich Trailer Park

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 50 $\mu g/m^3$	No. (%) of Daily Values > 100 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1996	16.1	4	0	87	119*
1997	16.7	0	0	46	50**

* Note: Samples taken on a three-day cycle
** Note: Monitoring ended May 31, 1997.

E.4 Total Suspended Particulate (TSP) Results

Sources for TSP are the same as those mentioned for PM_{10} and $PM_{2.5}$, but also include much coarser particles up to a mean diameter of 30 µm. Smaller particles come mainly from combustion sources or secondary pollutants. Larger particles typically come from mechanical processes such as wind blown dust, volcanic eruptions and grinding operations. Even though the smaller particles stay in the atmosphere longer, the larger TSP can remain in the atmosphere for several days.

The ministry operated one TSP sampler at Plaza for the federal government under the NAPS program, which lasted until 1998. TSP was normally measured for a 24 hour period on a 6-day cycle (i.e., once every sixth day).

Table E.4.1 shows the annual trend summary of TSP data for 1974-1998 at the federal monitoring site, which shows a decrease of about 55% in levels from 1981 to 1995. From 1995 to 1997 levels remained fairly constant, and then started increasing in 1998, with a 16.2% increase noted over the previous year. The annual average in 1998 was the highest recorded since 1992. The exceedance on March 18, 1998 was the highest 24-hour concentration recorded at that site since 1983.

Table E.4.1
Annual Trend Summary of Non-Continuous TSP Data at Plaza Using the Federal Monitor

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1974	111.3	5 (20.8%)	1 (4.2%)	257	24
1975	117.0	13 (30.2%)	6 (14.0%)	278	43
1976	127.0	6 (24.0%)	3 (12.0%)	526	25
1977	99.2	7 (21.2%)	3 (9.1%)	261	33
1978	216.5	33 (78.6%)	27 (64.3%)	379	42
1979	127.8	15 (29.4%)	10 (19.6%)	355	51
1980	86.8	4 (8.0%)	3 (6.0%)	238	50
1981	89.7	5 (8.5%)	3 (5.1%)	356	59
1982	77.3	6 (9.8%)	1 (1.6%)	219	61
1983	76.0	3 (5.9%)	2 (3.9%)	281	51
1984	62.3	3 (5.2%)	1 (1.7%)	236	58
1985	65.2	2 (3.8%)	0	195	53
1986	60.5	4 (7.4%)	0	184	54
1987	70.0	2 (3.7%)	0	186	54
1988	64.5	3 (5.3%)	3 (5.3%)	258	57
1989	58.9	4 (7.0%)	1 (1.7%)	200	57
1990	53.2	3(5.7%)	1(1.9%)	203	53
1991	49.1	1(1.7%)	0	178	59
1992	54.6	2(3.4%)	1(1.7%)	258	58
1993	45.5	1(1.7%)	0	163	58
1994	45.2	1(1.7%)	0	174	60
1995	40.3	0	0	146	56
1996	40.0	0	0	97	60
1997	40.8	0	0	145	59
1998	47.4	1(1.7%)	1(1.7%)	275	60

As well as the federal monitoring site, the Ministry also monitored TSP at several locations in Prince George from 1977 up to July 1990. The Ministry stopped monitoring TSP in 1990 and converted all their instruments to PM_{10} samplers. Tables E.4.2 to E.4.10 show the annual trend summary of TSP data at these sites.

Table E.4.2
Annual Trend Summary of Non-Continuous TSP Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1979	106.7	2 (20.0%)	2 (20.0%)	271	33	10
1980	86.9	4 (8.0%)	3 (6.0%)	238	26	50
1981	89.4	5 (8.3%)	3 (5.0%)	356	32	60
1982	60.1	1 (5.0%)	0	197	11	20
1983	60.0	1 (2.2%)	0	167	17	46
1984	59.5	3 (5.0%)	0	185	8	60
1985	63.2	1 (1.6%)	1 (1.6%)	290	9	61
1986	73.1	5 (8.6%)	3 (5.2%)	226	19	58
1987	71.8	3 (5.2%)	0	172	16	58
1988	62.9	3 (4.9%)	1 (1.6%)	256	19	61
1989	64.6	5 (8.2%)	2 (3.3%)	271	13	61
1990	58.4	1 (2.9%)	1 (2.9%)	260	17	34

Table E.4.3
Annual Trend Summary of Non-Continuous TSP Data at Van Bien

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1978	65.5	1 (3.3%)	0	193	22	30
1979	87.9	5 (12.2%)	2 (4.9%)	249	20	41
1980	68.5	5 (8.6%)	0	178	6	58
1981	-	-	-	-	-	0
1982	64.5	2 (4.8%)	0	154	10	42
1983	58.2	2 (3.6%)	0	198	15	56
1984	54.8	1 (1.8%)	0	180	5	57
1985	57.6	0	0	141	10	59
1986	63.4	4 (6.9%)	2 (3.4%)	245	11	58
1987	72.3	4 (7.0%)	1 (1.8%)	223	10	57
1988	60.5	2 (3.3%)	1 (1.8%)	203	14	61
1989	54.1	3 (4.9%)	0	170	7	61
1990	71.3	4 (14.3%)	0	181	13	28

Table E.4.4
Annual Trend Summary of Non-Continuous TSP Data at Jail

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1982	35.5	0	0	105	7	18
1983	43.7	1 (2.3%)	0	175	11	44
1984	34.2	0	0	107	5	60
1985	37.6	0	0	112	5	60
1986	49.1	2 (3.6%)	0	198	12	55

Table E.4.5
Annual Trend Summary of Non-Continuous TSP Data at Lakewood

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1982	48.1	0	0	116	11	48
1983	47.6	2 (3.6%)	1 (1.8%)	202	10	56
1984	41.8	0	0	146	10	55
1985	49.6	2 (3.4%)	0	182	5	59
1986	55.1	5 (8.5%)	1 (1.7%)	211	8	59
1987	55.4	1 (1.7%)	0	150	8	59
1988	45.8	2 (3.3%)	0	172	5	60
1989	39.5	1 (1.6%)	0	172	6	61
1990	52.9	1 (2.9%)	1 (2.9%)	287	10	35

Table E.4.6
Annual Trend Summary of Non-Continuous TSP Data at Foreman Flats

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1982	-	0	0	73	4	12
1983	44.9	1 (2.3%)	0	175	14	43
1984	36.8	0	0	97	5	57
1985	35.6	0	0	98	4	60
1986	36.6	0	0	116	8	51
1987	40.1	0	0	102	8	55
1988	39.4	0	0	132	9	61
1989	42.6	1 (1.6%)	0	187	0	61
1990	36.3	0	0	85	18	32

Table E.4.7
Annual Trend Summary of Non-Continuous TSP Data at Gladstone

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1979	58.7	3 (7.0%)	0	195	10	43
1980	52.0	2 (3.5%)	0	167	6	57
1981	52.5	3 (5.2%)	1 (1.7%)	207	12	58
1982	46.5	0	0	133	11	57
1983	50.8	1 (1.8%)	0	164	10	57
1984	46.8	1 (1.8%)	0	182	6	54
1985	43.3	0	0	138	2	60
1986	43.1	2 (3.6%)	0	181	5	56

Table E.4.8
Annual Trend Summary of Non-Continuous TSP Data at 5th Avenue Firehall

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1975	114.9	3 (33.3%)	3 (33.3%)	266	35	9
1976	25.0	0	0	62	3	4
1977	87.2	7 (16.7%)	2 (4.8%)	246	16	42
1978	89.1	4 (13.3%)	2 (6.7%)	274	21	30
1979	92.5	7 (15.6%)	5 (11.1%)	297	13	45
1980	69.2	4 (7.7%)	2 (3.8%)	288	11	52
1981	78.9	6 (9.8%)	4 (6.6%)	277	15	61

Table E.4.9
Annual Trend Summary of Non-Continuous TSP Data at Community Service Centre

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1976	127	6 (24.0%)	3 (12.0%)	526	25	25
1977	97.1	6 (20.0%)	3 (10.0%)	261	15	30
1978	217	32 (78.0%)	27 (65.9%)	379	44	41
1979	133	13 (31.7%)	8 (19.5%)	355	28	41

Table E.4.10
Annual Trend Summary of Non-Continuous TSP Data at Seymour

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 150 $\mu g/m^3$	No. (%) of Daily Values > 200 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Minimum Daily Value ($\mu g/m^3$)	Number of Samples
1977	64.8	1 (4.3%)	0	152	16	23
1978	63.8	1 (8.3%)	0	151	23	12
1979	71.1	2 (4.9%)	0	188	14	41

E.4.1 Sulphates, Nitrates and Lead in Total Suspended Particulate Results

The total suspended particulate filters from the federal monitoring site were analyzed to determine the amount of sulphate, nitrate, and lead in the airshed. Sulphate and nitrate are primarily secondary pollutants derived mainly from the oxidation of sulphur dioxide and nitrogen dioxide, respectively.

Both sulphate and nitrate compounds have been linked to respiratory irritation and disease, corrosion of materials and reduction of visibility. Lead enters the body primarily through ingestion and inhalation with subsequent absorption into the blood stream and distribution to all body tissues. Lead is known to degrade renal function, impair hemoglobin synthesis, and alter the nervous system.

Table E.4.11
Annual Trend Summary of (Non-Continuous) Sulphates, Nitrates and Lead in TSP at Plaza

Year	Annual Average ($\mu g/m^3$)			Ratio of SO_4 in TSP			Maximum Daily Value ($\mu g/m^3$)			Number of Samples
	Sulphate	Lead	Nitrate	Sulphate	Lead	Nitrate	Sulphate	Lead	Nitrate	
1974	-	0.854	-	-	0.82%	-	-	1.98	-	24
1975	-	0.704	-	-	0.70%	-	-	4.21	-	43
1976	-	0.716	-	-	0.75%	-	-	2.04	-	25
1977	-	0.787	-	-	0.94%	-	-	3.68	-	33
1978	-	0.784	-	-	0.51%	-	-	2.02	-	42
1979	7.96	0.515	1.44	8.33%	0.43%	1.68%	18.8	2.16	2.5	51/16*
1980	5.40	0.312	1.25	7.15%	0.40%	1.46%	14.0	1.07	5.6	50
1981	8.09	0.333	1.57	9.11%	0.40%	1.73%	43.3	0.91	4.8	59/19*
1982	-	0.290	-	-	0.44%	-	-	0.83	-	61/0*
1983	5.79	0.190	0.99	9.30%	0.28%	1.55%	15.2	0.89	3.5	51/21*
1984	4.04	0.164	0.73	8.41%	0.30%	1.47%	27.0	0.5	2.2	58
1985	3.64	0.125	0.78	6.27%	0.22%	1.41%	13.5	0.5	2.1	53
1986	4.59	0.139	1.19	8.81%	0.27%	2.36%	21.7	0.91	2.7	54
1987	5.54	0.093	0.82	7.72%	0.13%	1.25%	21.4	0.42	2.6	54
1988	4.60	0.067	1.00	7.45%	0.12%	1.88%	29.5	0.3	3.1	57
1989	4.99	0.078	0.81	8.80%	0.14%	1.67%	35.4	0.31	2.3	57
1990	3.71	0.032	0.85	8.91%	0.07%	2.03%	17.3	0.28	3.1	53
1991	3.75	0.014	0.72	9.05%	0.04%	1.89%	21.2	0.13	3.0	59
1992	4.05	0.017	0.67	9.23%	0.04%	1.56%	11.9	0.13	1.9	58
1993	3.95	0.009	0.80	9.73%	0.02%	2.17%	23.6	0.02	1.9	58
1994	3.29	0.004	0.39	9.50%	0.01%	1.10%	24.0	0.03	1.3	60
1995	2.54	0.005	-	8.51%	0.01%	-	18.2	0.02	-	56
1996	3.18	0.010	-	8.75%	0.03%	-	11.3	0.03	-	60
1997	3.60	0.017	-	8.88%	0.05%	-	16.8	0.05	-	59
1998	3.60	0.024	-	8.88%	0.07%	-	18.9	0.06	-	60

* SO4 and NO3 were not sampled for the full year

Table E.4.11 gives the annual trend in sulphate and lead levels in TSP at the Plaza site. In the past four years, levels have been increasing. It should be noted that annual average for sulphate increased from 1996 to 1997 and remained the same in 1998, yet SO_2 levels recorded at Plaza for the same NAPS schedule have gradually decreased from 1996 to 1998 (19.8, 16.5 and 15.1 $\mu g/m^3$, respectively). However, the ratio of sulphate in TSP did decrease in 1998. Levels for lead have been decreasing until 1994, when they starting increasing. This trend is similar to that of sulphates

The Ministry 24-hour Level A ambient objective for lead is 4 $\mu g/m^3$. Since monitoring began in 1990, all measurements taken for lead are well below this objective. At present, the Ministry does not have an objective for particulate sulphate.

E.4.2 Silicates in PM_{10} Results

From March 1994 until December 1994 the PM_{10} filters were analyzed to determine the amount of silicon on the filters. Silicon is not found free in nature, but occurs chiefly as the oxide and as silicates. Silicon is sampled to determine the amount of these compounds that exist in the airshed, which is an indication of the amount of crustal material that contributes towards PM_{10}.

Table E.4.12
Silicon Levels Recorded at Sites in Prince George

	Lakewood	CNR	BCR	Van Bien	Gladstone	Plaza
No. of Samples	49	46	40	39	51	51
No. of Samples < detectable	29	33	31	27	33	39
Average ($\mu g/m^3$)	0.034	0.043	0.056	0.039	0.040	0.043
Maximum ($\mu g/m^3$)	0.28	0.22	0.27	0.14	0.66	0.31

E.5 Carbon Monoxide (CO) Results

Carbon monoxide is a colourless, odourless and tasteless gas. It is toxic at sufficiently high concentrations and death can result from asphyxiation. Hemoglobin in the blood has an affinity for CO that is about 200 times greater than oxygen, reducing the blood's ability to carry oxygen.

Table E.5.1
1997-98 Monthly Summary of Carbon Monoxide (CC) Data at Sites in Prince George

	Monthly Average ($\mu g/m^3$)	**No. of 1-Hour Values >14300 $\mu g/m^3$**	**Maximum Hourly Average ($\mu g/m^3$)**	**No. Of 8-Hour Values >5500 $\mu g/m^3$**	**Maximum 8-Hour Average ($\mu g/m^3$)**
Lakewood					
Jan. '97	686	0	4192	0	2538
Feb. '97	1156	0	4192	0	3375
Mar. '97	334	0	2096	0	1450
period	**748**	**0**	**4200**	**0**	**3375**
Hart					
Apr. '97	79	0	2329	0	800
May '97	115	0	2329	0	1038
June '97	93	0	1164	0	900
Nov. '97	176	0	3493	0	1338
Dec. '97	366	0	9315	0	3350
Jan. '98	485	0	5822	0	3488
Feb. '98	1025	0	6986	0	3338
Mar. '98	141	0	3493	0	1750
period	**335**	**0**	**9300**	**0**	**3488**

Tables E.5.1 shows all the monthly CO levels ever recorded at sites in Prince George. Even with a short data base, the highest monthly average recorded at both sites occurred in February.

The hourly maximum level of 7,000 $\mu g/m^3$ recorded at the Hart in 1998 was just below the 90^{th} percentile of CO levels recorded at all sites in B.C. in 1998 (maximum of 9,661 $\mu g/m^3$ recorded at Richmond).

E.6.1 Formaldehyde (HCHO) Results

Formaldehyde is a colourless, flammable and reactive gas at ambient temperatures. It has a pungent odour detectable at low concentrations. Its vapour and solutions are known skin and eye irritants. It is known to cause irritation of the mucous lining in the eyes and upper airways.
Presently, formaldehyde is the only aldehyde for which the provincial government has an objective (One-hour Level A Objective of 60 $\mu g/m^3$).

Most of the formaldehyde is formed in the troposphere by the oxidation of hydrocarbons. Other natural sources include the decomposition of plants residues and the transformation of various chemicals emitted by foliage. Two of the main man-made sources are automobiles (without catalytic converters), and manufacturers of formaldehyde or of materials derived from, or treated with it.

Table E.6.1
1995-97 Monthly Summary of Formaldehyde ($\mu g/m^3$) Data at Sites in Prince George

Location	No. of samples	Maximum	Minimum	Average
SINTICH				
1996	120	10.2	<0.5	3.3
1997	50	5.3	<0.5	2.2
GLADSTONE				
1996	118	8.6	<0.5	2.3
1997	48	4.7	<0.5	1.7
PLAZA				
1995	25	15.0	0.9	3.6
1996	62	6.9	1.0	3.3
1997	25	7.3	0.7	2.4
BCR				
1995	25	17.7	0.7	4.7
1996	62	11.3	<0.5	3.6
1997	24	6.2	<0.5	2.4
Lakewood				
1995	23	9.1	0.5	3.6

Formaldehyde was monitored by a low flow vacuum pump drawing air through a DNPH (2,4-dinitrophenlyhydrazine) cartridge over a 24-hour hour period. This cartridge is later eluted and analyzed in a certified laboratory.

Table E.6.1 gives the ambient concentrations of formaldehyde monitored from December 1994 to June 1995 at Lakewood, BCR, and Plaza and again from December 1995 to May 31, 1997, at Plaza, BCR, Gladstone, and Sintich. Monitoring for the first period was to try to capture to days in which levels were expected to be high and is not representative of the typical levels expected at those areas in 1995. Note that the average concentration is calculated assuming all values below the minimum detectable concentration (MDC) to be one half the MDC.

These formaldehyde levels are 24-hour averages, but the B.C. objective is 60 $\mu g/m^3$ on an hourly basis. Multiplying the 24-hour values by a conservative conversion factor of four yields no values that exceeded the B.C. objective.

E.6.2 Volatile Organic Compounds (VOC) Results

VOC is a general term for a class of organic compounds primarily made up of hydrocarbons. Hydrocarbons contain not only carbon atoms, as all organic compounds do, but also, hydrogen atoms. With the exception of methane, the primary sources of VOC are industry, vehicle emissions, refrigerants, and cleansers. Many VOC are not primary pollutants and are not harmful in and of themselves. However, many VOC do react with other chemicals to produce secondary pollutants such as ozone.

VOC were monitored at three locations (10 samples at Plaza, 8 samples at BCR and 6 samples at Lakewood) from December 1994 to June 1995. VOC were monitored using a Tenax cartridge. These cartridges were then sent to a laboratory for analysis. Most of the sampling took place during conditions conducive to poor air quality and the sampling period ranged from 12 hours to 24 hours.

Table E.6.2 gives the ambient concentrations of different VOC monitored during these periods. Note that the average concentration is calculated assuming all values below the minimum detectable concentration (MDC) were one-half the MDC. The provincial government has not established objectives for any VOC.

Table E.6.2

Concentrations of Various VOC ($\mu g/m^3$) Recorded from December 1994 to June 1995

POLLUTANT	# above MDL			MAXIMUM			MINIMUM			AVERAGE		
	Plaza	BCR	Lake.	Plaza	BCR	Lake.	Plaza	BCR	Lake.	Plaza	BCR	Lake.
Chloromethane	0	2	1	< 0.03	6.25	0.73	< 0.03	< 0.03	< 0.03	< 0.03	1.22	0.13
Bromomethane	1	3	1	0.10	0.22	0.06	< 0.05	< 0.05	< 0.05	< 0.05	0.08	< 0.05
TriClFluoromethane	9	6	3	11.58	16.84	1.98	< 0.01	< 0.01	< 0.01	2.28	3.07	0.50
1,1-Dichloroethene	5	4	4	0.14	1.07	0.09	< 0.01	< 0.01	< 0.01	0.05	0.18	0.05
Dichloromethane	10	7	5	4.74	2.26	1.38	0.03	< 0.01	< 0.01	0.95	0.57	0.57
Chloroform	8	6	3	0.10	0.14	0.03	< 0.01	< 0.01	< 0.01	0.03	0.07	0.02
1,1,1-TriClEthane	9	8	6	0.85	0.67	0.27	< 0.01	0.14	0.04	0.25	0.44	0.18
1,2 Dichloroethane	4	5	1	0.03	0.16	0.06	< 0.01	< 0.01	< 0.01	0.01	0.05	0.01
Carbon Tetrachloride	9	8	6	0.29	0.67	0.18	< 0.01	0.10	0.02	0.09	0.32	0.09
Benzene	10	8	6	4.71	3.33	1.43	0.09	0.38	0.11	1.06	1.66	0.94
TriChloroethene	4	8	3	0.03	0.49	0.08	< 0.01	0.02	< 0.01	0.01	0.10	0.02
Toluene	10	8	6	2.62	2.96	1.43	0.42	0.15	0.56	1.33	1.25	0.98
Tetrachloroethyene	10	6	6	0.90	1.23	0.46	0.12	< 0.01	0.06	0.42	0.31	0.18
Chlorobenzene	2	2	0	0.03	0.12	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01
Ethylbenzene	10	7	6	0.85	1.62	0.92	0.23	< 0.01	0.29	0.61	0.65	0.48
m&p-Xylene	10	8	6	1.92	3.65	2.09	0.51	0.27	0.71	1.42	1.65	1.30
Bromoform	2	3	3	0.51	0.10	0.05	< 0.01	< 0.01	< 0.01	0.06	0.02	0.02
Styrene	10	6	5	0.33	0.24	0.24	0.06	< 0.01	< 0.01	0.17	0.12	0.11
O-Xylene	10	8	6	1.25	2.26	1.43	0.34	0.56	0.46	0.88	1.03	0.78
1,2 Dichlorobenzene	1	1	0	0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
1,4 Dichlorobenzene	10	8	6	0.19	0.75	0.07	0.06	0.05	0.02	0.12	0.22	0.04

* MDL (Minimum Detectable Limit) for all VOC were 0.01 $\mu g/m^3$ except for chloromethane and Bomomethane which were 0.03 and 0.05 $\mu g/m^3$ respectively .

** Lake. - designates the Lakewood Station

E.6.3 Polycyclic Aromatic Hydrocarbons (PAH) Results

Polycyclic aromatic hydrocarbons are emitted during such processes as the incomplete combustion of biomass or fossil fuels.

PAH were monitored at three locations (14 samples each at BCR and Lakewood and 10 samples at Plaza) from December 1994 to June 1995. PAH were sampled using a PUF Hi-Vol sampler. These samples were sent to a laboratory for analysis. Most of the sampling took place during conditions conducive to poor air quality and the sampling period ranged from 12 hours to 24 hours.

Table E.6.3 gives the ambient concentrations of different PAH monitoring during these periods. Note that the average concentration was calculated assuming all values below the minimum detectable concentration (MDC) to be one half the MDC.

Table E.6.3

Concentrations of Various PAHs (x 10^{-3} µg/m^3) Recorded from December 1994 to June 1995

POLLUTANT	# above MDL			MAXIMUM			MINIMUM			AVERAGE		
	Plaza	BCR	Lake.	Plaza	BCR	Lake.	Plaza	BCR	Lake.	Plaza	BCR	Lake.
Benz(a)anthracene	10	11	14	2.80	0.69	8.00	0.12	< 0.05	0.07	0.96	0.24	2.13
Dibenzo(a,h)anthracene	3	0	8	0.20	< 0.10	0.40	< 0.10	< 0.10	< 0.10	0.08	< 0.10	0.16
Chrysene	10	13	14	3.00	1.00	6.90	0.18	< 0.05	0.11	1.21	0.36	2.48
Benzo(b)fluoranthene	10	12	14	3.20	6.00	8.60	0.22	< 0.05	0.05	1.22	0.70	2.57
Benzo(k)fluoranthene	10	10	13	0.84	0.31	3.70	0.06	< 0.05	< 0.05	0.37	0.11	0.96
Benzo(g,h,i)perylene	10	7	13	2.10	0.80	3.70	0.10	< 0.10	< 0.10	0.84	0.24	1.60
Pyrene	10	13	14	8.40	4.20	16.00	0.93	< 0.05	0.78	3.83	1.02	6.96
Benzo(a)pyrene	10	10	14	1.90	0.48	5.00	0.09	< 0.05	0.06	0.67	0.16	1.68
Indeno(1,2,3-c,d)pyrene	8	8	12	1.90	0.60	4.30	< 0.10	< 0.10	< 0.10	0.69	0.19	1.55
Acenaphthene	10	14	14	11.00	20.00	12.00	0.50	0.32	0.29	3.68	5.35	3.49
Acenaphthylene	10	14	14	45.00	11.00	56.00	0.51	0.34	0.62	11.96	3.47	20.99
Anthracene	10	14	14	4.40	2.10	9.80	0.51	0.06	0.27	1.88	0.58	3.58
Fluoranthene	10	13	14	7.80	4.10	22.00	0.94	< 0.05	0.81	3.68	1.05	8.03
Fluorene	10	14	14	15.00	11.00	21.00	1.90	0.16	1.70	8.29	4.16	9.35
Naphthalene	10	14	14	47.00	86.00	360.00	2.70	3.30	1.70	15.04	25.70	46.06
Phenanthrene	10	14	14	32.00	23.00	51.00	7.10	0.18	3.60	16.49	6.67	21.64
TOTAL PAH	10	14	14	182.00	104.00	440.00	21.00	7.30	15.00	70.80	49.66	133.00

* MDL (Minimum Detectable Limit) for PAH were either 0.0001 or 0.00005 µg/m^3.

** Lake. - designates the Lakewood Station

B.C. does not have air quality objectives for PAH. Benzo(a)pyrene was the sole PAH value that exceeded any available objectives. Both Plaza and Lakewood recorded levels greater than the lowest objective, from Ontario. Lakewood site recorded nine occurrences of exceedences and Plaza recorded two. All exceedences were recorded between December 28, 1994 to February 28, 1995.

E.7 Dustfall Results

Dustfall is a measurement of the amount of particulate matter that settles out of the atmosphere or that is washed out of the air by rainfall. Most of the particulate which form dustfall will range in size from approximately 20 to 200 micrometres. Particulate in this size range are not inhaled into the lungs. The major sources of dustfall are wind blown natural sources and traffic generated dust. Other sources in Prince George include beehive burners and open burning. Dustfall is collected in an open mouthed canister over the period of a month. A liquid (usually de-ionised water, isopropyl alcohol is added in winter) is maintained in the canister to prevent blow out of dust.

The annual dustfall summary collected at the four monitoring sites are summarised in Table E.7.1 – E.7.4. The dustfall program was terminated after June 1994.

Table E.7.1
Summary of Dustfall Data at Plaza ($mg/dm^2.d$)

Year	Average ($mg/dm^2.d$)	Number of Samples	No. of Samples	
			> 1.75	> 2.90
1980	1.64	10	5 (50%)	0
1981	1.73	14	6 (43%)	0
1982	1.34	12	3 (25%)	0
1983	1.21	12	2 (17%)	0
1984	0.97	12	0	0
1985	1.02	12	1 (8%)	0
1986	1.20	11	1 (9%)	0
1987	1.36	12	2 (17%)	0
1988	1.44	12	2 (17%)	0
1989	0.99	12	1 (8%)	0
1990	1.24	12	1 (8%)	0
1991	1.06	11	1 (9%)	0
1992	0.96	8	0	0
1993	0.81	10	0	0
1994	0.96	6	0	0

Table E.7.2
Summary of Dustfall Data at Foreman Flats ($mg/dm^2.d$)

Year	Average ($mg/dm^2.d$)	Number of Samples	No. of Samples	
			> 1.75	> 2.90
1982	1.45	9	4 (44%)	0
1983	0.95	12	0	0
1984	0.99	12	1 (3%)	0
1985	0.65	12	0	0
1986	0.78	11	0	0
1987	1.08	12	1 (3%)	0
1988	1.05	12	0	0
1989	1.11	12	2 (17%)	0
1990	0.95	12	2 (17%)	0
1991	1.02	12	1 (8%)	0
1992	0.76	8	0	0
1993	0.94	10	1 (10%)	0
1994	1.10	6	1 (17%)	0

Table E.7.3
Summary of Dustfall at Van Bien ($mg/dm^2.d$)

Year	Average ($mg/dm^2.d$)	Number of Samples	No. of Samples	
			> 1.75	> 2.90
1982	0.63	10	0	0
1983	0.65	12	0	0
1984	0.62	12	0	0
1985	0.54	12	0	0
1986	0.61	12	0	0
1987	0.86	11	0	0
1988	0.76	11	0	0
1989	0.66	11	0	0
1990	0.82	11	0	0
1991	0.93	10	1 (10%)	0
1992	0.97	8	1 (8%)	1(8%)
1993	0.81	10	1 (10%)	0
1994	0.80	6	0	0

Table E.7.4
Summary of Dustfall Data at Lakewood ($mg/dm^2.d$)

Year	Average ($mg/dm^2.d$)	Number of Samples	No. of Samples	
			> 1.75	> 2.90
1982	0.34	11	0	0
1983	0.37	12	0	0
1984	0.39	12	0	0
1985	0.29	12	0	0
1986	0.38	12	0	0
1987	0.57	12	0	0
1988	0.73	12	0	0
1989	0.54	11	0	0
1990	0.65	12	1 (8%)	0
1991	0.47	11	0	0
1992	0.49	7	0	0
1993	0.74	8	1 (13%)	0
1994	0.47	6	0	0

Appendix "F"

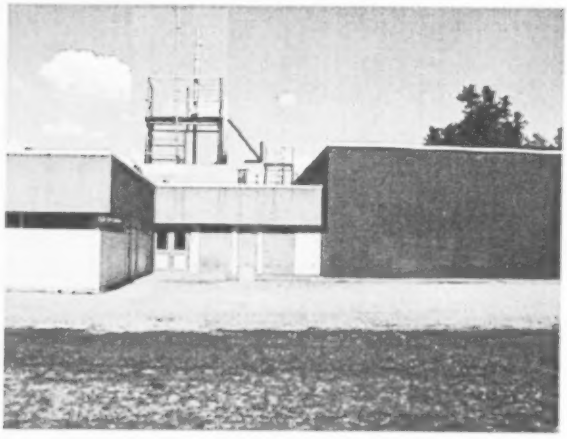
Photographs of the Monitoring Sites in Prince George

Lakeview Elementary looking towards the east

CNR site (Lakeland Mills) looking towards the south

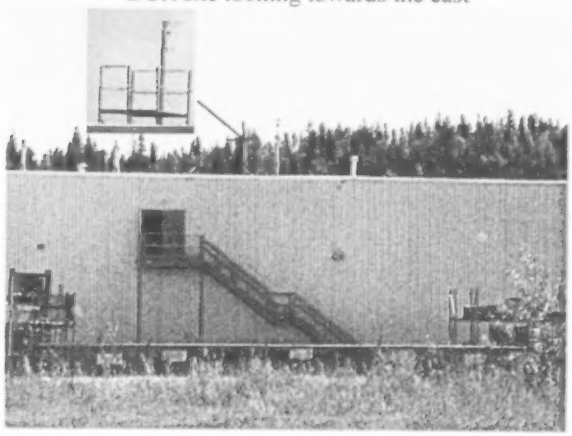
CBC Transmitter site looking towards the west

Gladstone School looking towards the north



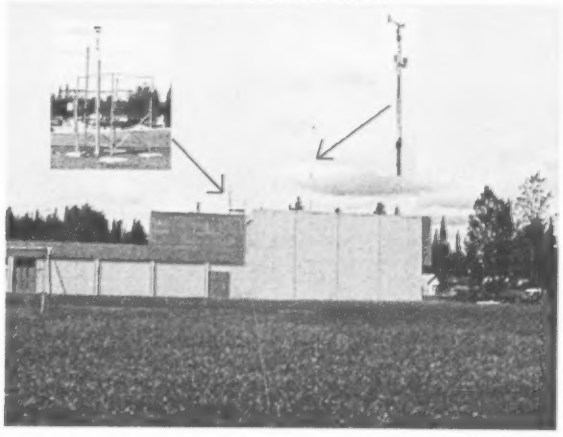
Jail looking towards the north

BCR site looking towards the east

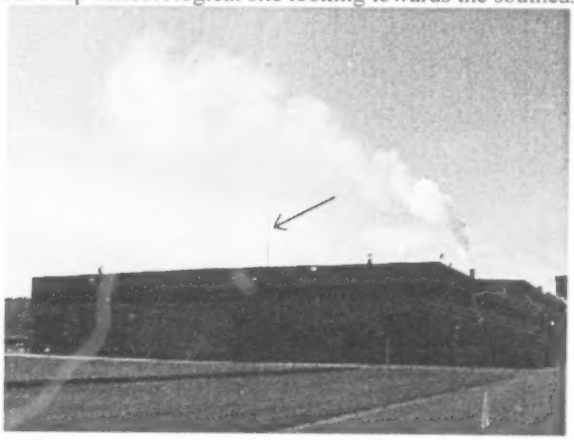


Plaza's ambient and meteorological site looking towards the southwest

Glenview ambient and meteorological site looking towards the west



P.G. Pulp meteorological site looking towards the southeast



Northwood meteorological site looking towards the east.

Appendix "G"
Glossary

Airshed:
The mass of air contained within a certain boundary (usually topographical boundary).

Aldehydes:
An organic compound that contains an oxygen atom doubly bonded to a carbon atom and possesses at least one hydrogen atom.

Ambient Air:
The portion of the atmosphere, external to buildings, to which the general public has access; open air.

Anthropogenic:
Referring to environmental alterations resulting from the presence or activities of humans.

Carcinogen:
An agent that incites development of cancer.

CO:
Carbon monoxide. A colourless, odourless and poisonous gas which is produced as a result of incomplete combustion of fossil fuels.

Detection Limit:
The minimum concentration of a compound contaminant that can be determined by a specific analytical method.

H_2S:
Hydrogen Sulphide. A colourless gas having a characteristic odour of rotten eggs.

HCHO:
Formaldehyde. The simplest member of the aldehyde group.

Inversion:
A meteorological condition in which a layer of warm air resides over a layer of cold air (usually occurring during nights when the sky is clear). Pollution is trapped below this warm air resulting in poor air quality over an area.

Level A Criteria:
A Criteria established to provide the basis for an anti-degradation policy for undeveloped areas with an adequate safety margin.

Level B Criteria:
A criterion established to provide adequate protection against adverse effects on personal health and comfort, animals, vegetation, soil, water, materials and visibility.

Level C Criteria:
A criterion established to provide protection against health effects that are specific to each contaminant.

Micron:
Micrometre (µm). 1 µm = 0.001 millimetres.

MIS:
Meteorological Information Station. Usually measuring continuous wind speed and direction.

NAPS:
National Air Pollution Surveillance. A federal schedule in which pollutants are monitored for a 24 hour period (from midnight to midnight) once every six days.

NO_2:
Nitrogen Dioxide. A reddish brown gas with a pungent and irritating odour at high concentrations.

NO:
Nitric Oxide. A colourless odourless gas emitted from combustion sources.

NO_x:
Oxides of nitrogen. Emitted from combustion sources. Assumed to be the sum of nitrogen dioxide and nitric oxide concentrations in the atmosphere.

O_3:
Ozone. The main constituent of smog found in the lower atmosphere and, when found in the upper atmosphere (stratosphere), a filter for ultra violet radiation.

PAH:
Polycyclic Aromatic Hydrocarbons are probable human carcinogens emitted during such processes as the incomplete combustion of biomass.

Percentile:
The percentage of the data set that lies below the stated value. For example, if the 70 percentile value is 10 $\mu g/m^3$, then 70% of the data are equal to or below 10 $\mu g/m^3$.

PGAATC:
Prince George Ambient Air Technical Committee. A committee that consists of BC Environment, Ministry of Health, Northwood, Canfor pulp and paper mills, and Husky.

PM_{10}:
Particulate matter that are less than 10 micrometres (0.000,01 metre) in diameter.

$PM_{2.5}$:

Particulate matter that are less than 2.5 micrometres (0.000,0025 metre) in diameter.

PPB:

Parts (of contaminant) per billion (parts of air)

Primary Pollutant:

A contaminant which is directly emitted to the atmosphere.

Secondary Pollutant:

A contaminant which is formed from other pollutants present in the atmosphere.

SO_2:

Sulphur dioxide. A corrosive gas produced mainly from the combustion of fossil fuels that contain sulphur.

TRS:

Total reduced sulphur. Main components include hydrogen sulphide, methylmercaptan, dimethyldisulphide and dimethylsulphide.

TSP:

Total Suspended Particulate matter that range in diameter from 0.001 micrometre to 100 micrometre.

VOC:

Volatile organic compounds. Emitted from sources such as oil-based paints, automobiles and dry cleaning fluids. A catalyst in the generation of tropospheric ozone.

$\mu g/m^3$:

Micrograms (0.000,001 grams) of contaminant per cubic metre.

µm:

Micrometre (0.001 millimetres).